THE PRELIMINARY LOCATION OF A PROPOSED HIGHWAY BY PHOTOGRAMMETRIC SURVEYS

JULY 1958
NO. 18

by

D. A. BAILEY

Joint Highway Research Project

PURDUE UNIVERSITY
LAFAYETTE INDIANA

FINAL REPORT

THE PRELIMINARY LOCATION OF A

PROPOSED HIGHWAY

BY PHOTOGRAMMETRIC SURVEYS

TO: K. B. Woods, Director — July 9, 1958

FROM: H. L. Michael, Assistant Director — File: 1-4-13, Project: C-36-32M

Attached is a copy of a final report entitled "The Preliminary Location of a Proposed Highway by Photogrammetric Surveys" by Dale Alden Bailey. The project was developed under the supervision of R. D. Miles, and was used by Mr. Bailey in partial fulfillment of the requirement for the Master's Degree.

The report was also used by Mr. Bailey in the preparation of a technical paper for the Annual Purdue Road School, April, 1958.

The report is presented for the record.

Respectfully submitted,

Harold L. Michael

Harold L. Michael, Assistant Director
Joint Highway Research Project

HLM:rdm

Attachment

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Dale Alden Bailey

Joint Highway Research Project
File: 1-4-13
Project: C-36-32M

Purdue University
Lafayette, Indiana

July, 1958

ACKNOWLEDGMENTS

The author wishes to take this opportunity to acknowledge with sincere appreciation the Joint Highway Research Project, Purdue University, Professor H. L. Michael, Assistant Director, and Purdue University School of Civil Engineering, K. B. Woods, Head, who made possible the carrying out of this project; The Indiana State Highway Department for providing aerial photograph negatives, maps, mosaics, and other information necessary to complete this project.

Particular gratitude is expressed to Professor Robert D. Miles, Research Engineer, for supervision and assistance in carrying out this project.

Others rendering assistance were William B. Prescott, Indiana State Highway Department, who gave the author instruction in Kelsh Plotter operation procedures, carried out some field surveys to obtain picture point elevations, and ran an accuracy check profile line; Duane Sargent, William Logan, and John Spaulding, highway technician trainees, who helped with field surveys, worked on the mapping process with Kelsh Plotter, and who aided in drafting the map manuscript; John Irwine and Maurice Drake, engineering undergraduates, who assisted in surveying plotting control; Robert W. Lowry and Paul M. Weckesser, Graduate Research

Assistants, who assisted in making field surveys and calculations; Emmett Black, who assisted in field surveys and made photographic and ozalid reproductions; Mrs. Ruth Mary Porter and Mrs. Virginia Sherry, who typed the manuscript; and Mrs. Jacqueline Devlin, who worked on drafting and preparation of the manuscript.

Credit should be given to Abrams Aerial Survey Corporation, who took the aerial photographs and prepared very high quality glass diapositive plates and photographs.

The work was carried out using the facilities of the Air Photo Laboratory in the Civil Engineering Building at Purdue University.

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ABSTRACT

Bailey, Dale A., M. S. C. E., Purdue University, June 1953. The Preliminary Location of a Highway by Photogrammetric Surveys. Major Professor: R. D. Miles.

This thesis pertains to the use of aerial photography and photogrammetric mapping as they are related to highway location and design. The study was designed as a preliminary location and design project of a part of the proposed Interstate Highway system which will cross the Knobstone Escapment in Floyd County, Indiana.

The purpose of the study was to investigate the procedures used in photogrammetric mapping for preliminary location studies of several alternate routes of a section of highway.

An area reconnaissance study using field and photo interpretation techniques was conducted to collect data on the existing transportation system, existing horizontal and vertical ground control for mapping, land use, and traffic. Field surveys were made to obtain additional ground control for photogrammetric mapping and to obtain a test profile for accuracy checks of the photogrammetric technique. A strip map was made at a scale of 200 feet-per-inch with a 10 foot contour interval using a Kelsh stereoplotter and aerial photographic dispositives at a scale of 800 feet-per-inch.

Three alternate routes were selected using the map and aerial photographs. Two routes were open cut and one

route contained a tunnel. Preliminary plans and profiles and earth quantities were developed to assist in an economic comparison using the cost benefit method.

The study indicated that the photogrammetric techniques used produced a map that complied with National Standards of Map Accuracy for the test profile determined. The study also indicated that in the economic comparison of the tunnel route with the best of the two open cut routes that a benefit cost ratio of 0.91 was obtained using projected 1975 traffic data even though it was estimated that the tunnel route would cost approximately 2.2 times as much as the open cut route.

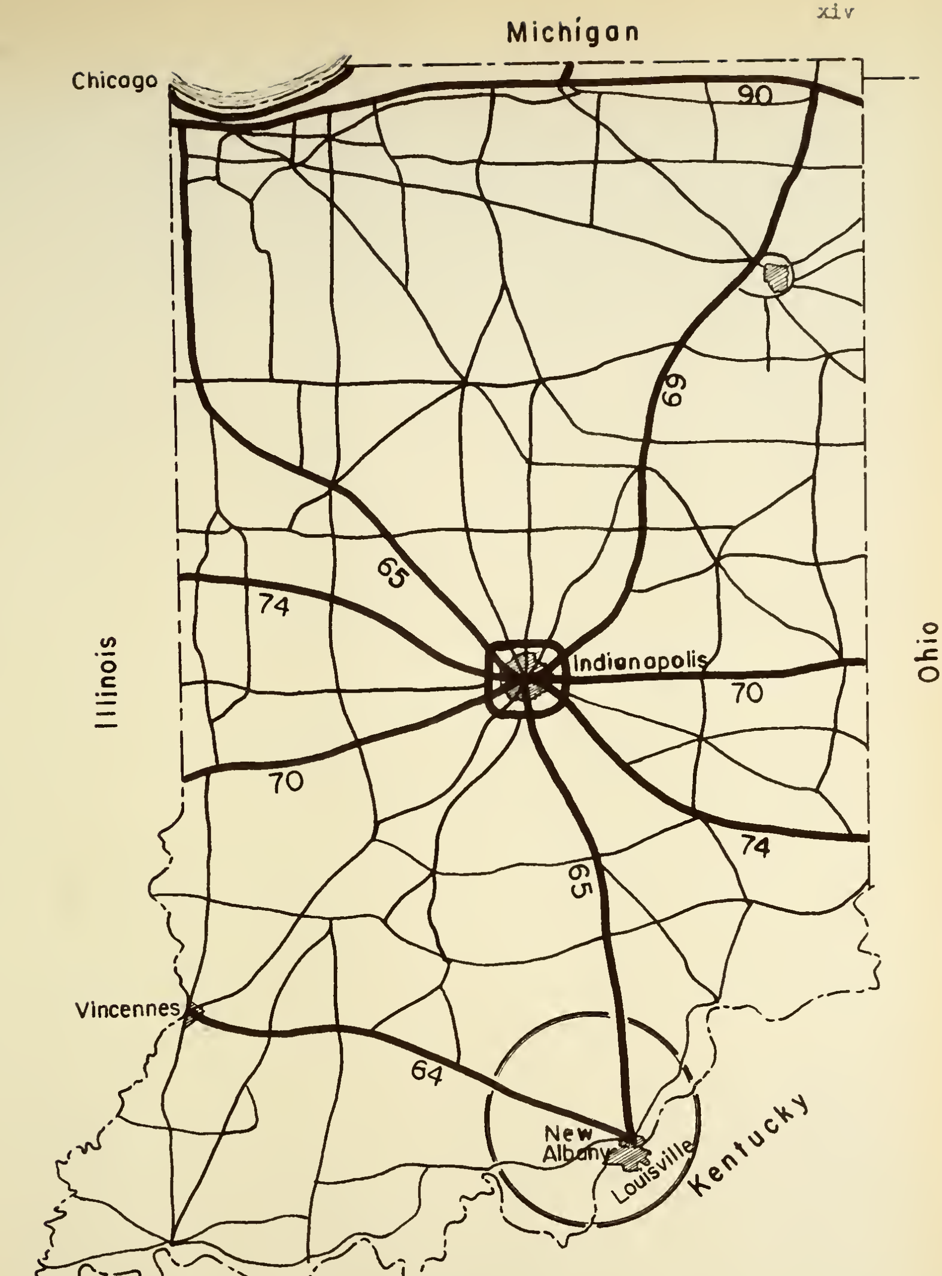
FOREWORD

The research reported here concerning photogrammetry in highway preliminary design has been carried out under the sponsorship of the Joint Highway Research Project, a division of the Engineering Experiment Station at Purdue University. This research work has been approved by an advisory board made up of personnel of the Indiana State Highway Department and the Civil Engineering school. The aims of the Joint Highway Research Project are: "To make basic studies of materials and methods for the purpose of facilitating the economic design, construction, and maintenance of county and state highways; to make miscellaneous studies; and to provide experience and advanced instruction in fundamentals of highway engineering and related research."

The purpose of this thesis project is to make a study of the procedures to be used while making a photogrammetric map for preliminary location studies of several alternate routes of a section of highway. The site chosen for this study is the Knobstone Escarpment area at New Albany, Indiana, where Interstate Highway #64 is scheduled to be built to roughly parallel the present route of highway US #150.

It is hoped that this research will aid the State Highway Department in designing future highways using their own photogrammetric branch or the services of consulting photogrammetric organizations.

The site of the area studied is shown in Plate 1.



INDIANA
INTERSTATE AND PRIMARY SYSTEM

PLATE I

CHAPTER I

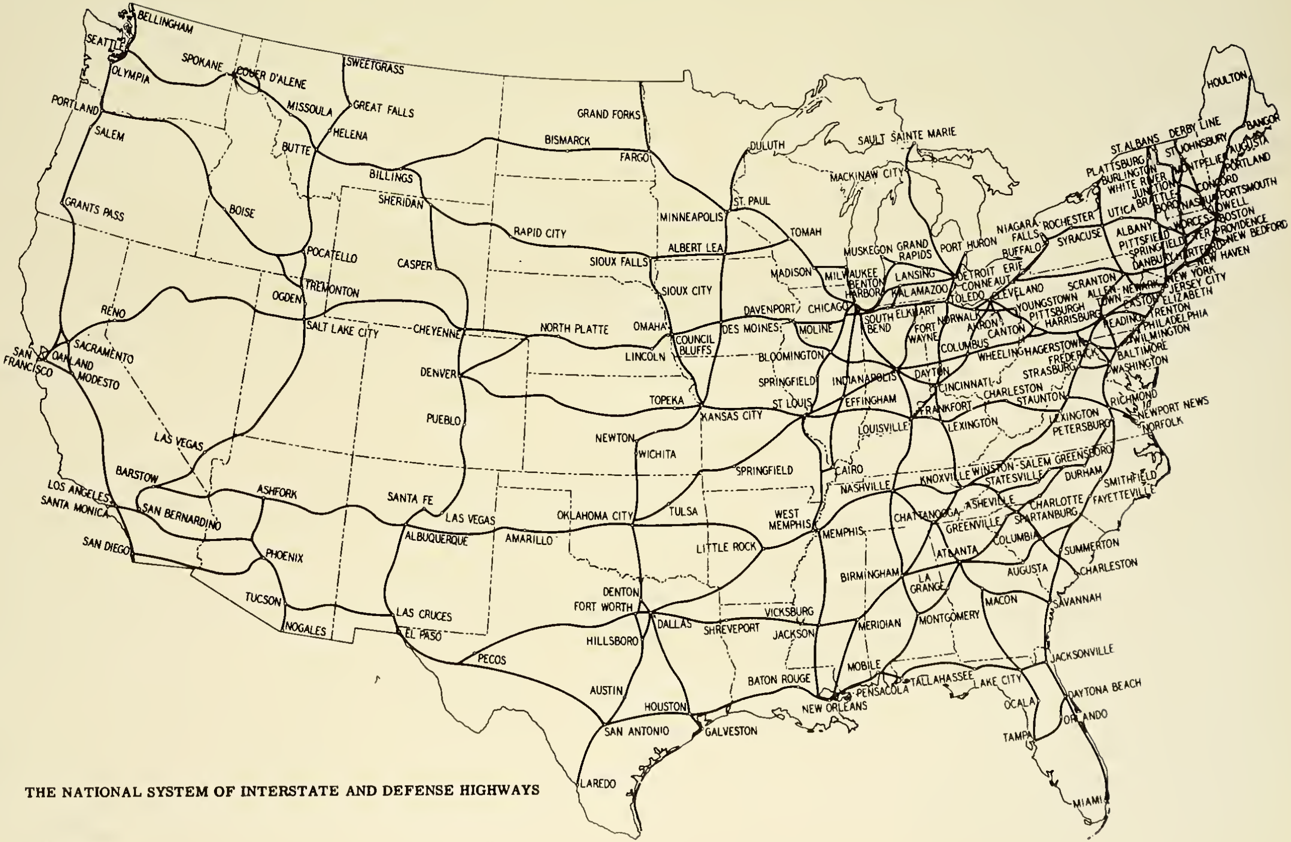
THE PRELIMINARY LOCATION OF A PROPOSED HIGHWAY BY PHOTOGRAMMETRIC SURVEYS

Introduction

The expansion and improvement of the existing road network of 3.4 million miles has already been initiated by the launching of construction of the new federal aid interstate limited access highway system shown in Figure 1. The predicted increase of motor vehicles from the present 65 million to 81 million by 1965 will assure a much greater expansion of the road system than has heretofore been predicted (17). There have been requests to add 13 thousand miles to the already approved 41,000 mile interstate system shown in Figure 1. The interstate system may appear to be the outstanding project because it will entail so much new alignment. There will also need to be tremendous improvements made in the primary and secondary road systems.

The urgency for the road improvements together with a disproportinate increase in the engineering manpower supply makes it necessary to use all the modern means available to rapidly map, plan, and design the highways of the future.

There has been a growing consensus of opinion that photogrammetric techniques, coupled whenever possible with electronic devices, can provide the answer to the manpower



THE NATIONAL SYSTEM OF INTERSTATE AND DEFENSE HIGHWAYS

COMM-DC-10688

FIG. 1

and time shortages. Mr. G. D. McCoy , State Highway engineer of California and President of the American Association of State Highway Officials has stated "The application of photogrammetry and automation techniques, in combination, is regarded as the greatest advance in the science of highway engineering in many years" (26).

An estimate made by the Photogrammetry Laboratory of Massachusetts Institute of Technology (MIT) that due to the overwhelming acceptance of photogrammetry $200,000,000.00 will be spent in its use in the construction of the $88.6 billion highway program over the next twelve to thirteen years (26). Another study at MIT predicts that to meet the demands of the new highway program the present private photogrammetric force of 2,874 employed by 50 firms will have to be greatly expanded (26).

Ohio estimates that by using photogrammetry to mechanize highway design that savings of 60 percent in manhours are possible in location studies, 40 percent in design costs, and 5-10 percent in construction (30).

The California Division of Highways is another example of an agency using photogrammetric techniques as aids to highway location studies and also final design. They have abandoned plane table mapping for preliminary surveys after discovering these maps to be less accurate than maps produced by photogrammetry. California too has used photogrammetric maps for contract plans. They have found that on large contracts for which quantities were calculated from

photogrammetric maps and which were checked with volumes calculated after construction by ordinary methods, the maximum error was 3.8 percent (13). This error they thought to be very reasonable considering they believe that they can only estimate shrinkage factors to within 5 percent. California estimates that they save 75 percent in cost over conventional ground mapping and 80 percent in manpower. Another report from California estimates that photogrammetry saves the time and effort of 200 engineers a year (14).

Recent aerial surveys carried out for the Illinois Highway Department, which were used for preliminary design studies, and from which cross sections were taken photogrammetrically showed that when compared with field survey cross sections, there was an average difference of from 1 to 3 percent in volume calculations (28).

The photogrammetric cross sectioning of a highway can be done at great speed. It has been estimated that in many cases especially in flat type terrain 75 cross sections per mile are sufficient and that a stereo operator can take about 50 cross sections per day (28).

It is the feeling of some that existing photogrammetric methods have tremendous possibilities of being improved. There has been some research into using automatic contouring, as mentioned by D. Esten (23), using photomultipliers which transform light from the two conjugate rays into voltages and which automatically seek a place where the voltages from

the multipliers are equal. There also is possible integration of photogrammetry with electronic computers into an automatic system whereby terrain data are fed directly to a computer by means of a punch card or by tape system eliminating the need for plotting the map and cross sections conventionally (30). The computer then would select the best line according to the instructions given it in a program. The computer could even be directed to take into account land values and soil or rock excavating costs in order to select the most economic alignment.

Besides the main advantages indicated previously in saving of manpower, time, and money there are other advantages to be noted. An important one of these is the usual greater width of terrain information obtained in a photogrammetric map than in the conventional type. Another important advantage is that the completion of plans early; possibly before extensive ground surveys are carried out, permits right-of-way acquisition in early stages thus reducing costs and permitting restrictions to be put on right-of-way thereby stopping owners from carrying out new construction. It is also possible to retrace old boundaries not detected by ground surveys. Boundaries surveyed in 1741 in Petersham, Massachusetts, can still be traced in pictures today (15).

Photogrammetric maps provide a more complete inventory of land utilization. By making use of a photo-interpreter in conjunction with photogrammetric data, drainage, soil

characteristics, and rock influence can be determined clearly. Photographs, being easier to read than maps, are therefore of more value than topographic maps for public hearings and talks with laymen.

Aerial photographs taken before and after construction are good exhibits in case of damage suits as they give exact data in both situations.

Purpose

The purpose of this project is to make a study, using photogrammetric mapping techniques, of the reconnaissance and preliminary design of alternate routes for a proposed highway relocation.

It is the intention of this study to assist the Indiana State Highway Department in this specific relocation project and to develop procedures and methods which will assist in further design projects using photogrammetry.

Scope

The region for study of the proposed relocation of a highway was selected near New Albany, (Floyd County) Indiana, and involved the mapping by photogrammetric means that portion of the Knobstone Escarpment roughly paralleling highway US #150. The area was mapped with a Kelsh stereo-plotter using aerial photography secured from the Indiana State Highway Department.

The area mapped was about 4 miles long, extending from Falling Run at New Albany west to Little Indian Creek on the

west side of the escarpment. The width of the map area was about 2 miles and extended from just north of highway US #150 south to the south side of Old Vincennes Road.

The mapping and design first required a reconnaissance study of the area using small scale topographic maps and mosaics in order to select possible routings and determine what survey control would be needed for mapping. It was necessary for a crew of three men to spend about 10 days conducting control surveys in the area. The survey controls involved running levels for vertical control, taping for horizontal control and some traversing for coordinate control.

In order to check the accuracy of the map an Indiana State Highway Department crew spent about 4 days in the area running a check line of profile elevations.

A benefit analysis was carried out comparing two routes using cost data supplied by the Joint Highway Research Project Traffic Laboratory at Purdue University and several editions of Engineering News-Record.

CHAPTER II

PHOTOGRAMMETRY AS USED IN HIGHWAY DESIGN

Introduction

There are many ways in which aerial photography can be used for highway design purposes. Vertical aerial photography can be used in the form of uncontrolled and controlled mosaics, or to make sketch maps suitable for some design purposes. Oblique aerial photography can be used in route reconnaissance and is also quite often used for presentation of highway planning to public meetings(54).

The important use of aerial photography is in the production of various types of maps by photogrammetric and interpretative methods for use in highway planning and design studies. The most important type of map is the topographic map made to various scales for various purposes and showing the natural relief and natural and cultural features present. Another type of map that can be produced from air photos is the engineering soil map detailing the outline and extent of various types of soils and rocks. Still another type of map produced is the drainage map which can be used to determine run-off areas and characteristics used in the design of drainage structures. Land use maps which can be produced from aerial photography are of special value when economics become a controlling factor in route location[(44)].

The relative values of property can be often very closely determined by stereoscopic study of the aerial photographs.

It would seem that in order to develop a logical and easily followed design procedure, that the design of a highway facility be divided into certain phases or stages, and that certain types of maps would be more suitable for each of these steps in design process.

Pryor in 1947 listed four stages in selecting a highway location that have been generally followed by various agencies in highway work ([37]). He also suggested suitable scale ranges for maps to be used in each stage as shown in Figure 2.

1. Reconnaissance of Area: In this stage of design, attempts are made, by studying a large area, to select on the basis of topography and other outstanding factors, possible bands of terrain that would be suitable for a more detailed study. Scales suitable for this reconnaissance study could be from 5000 feet-per-inch to 500 feet-per-inch.

2. Reconnaissance of Alternate Routes: In this stage maps varying from 100 feet-per-inch to 200 feet-per-inch enable the engineers to make rough estimates of

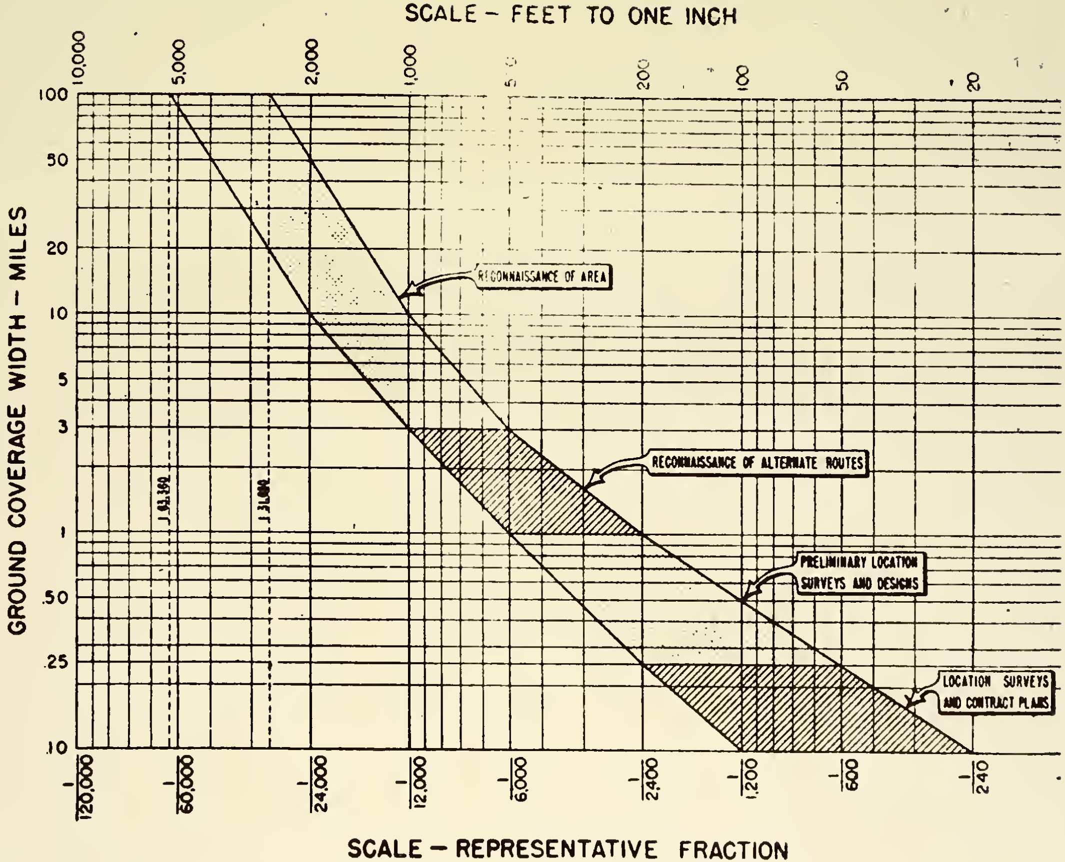


FIG. 2 HIGHWAY DESIGN IN FOUR STAGES

earthwork, structures, distances, grades, and soil conditions so that a readjusted or refined route can be selected by the comparison of cost estimates.

3. Preliminary Location Surveys: After having selected a route, or several routes as suitable, another detailed study should be made by the use of maps of from 500 feet-per-inch to 50 feet-per-inch; thus, enabling the designer to select the best location on each alternate route.

4. Location Survey and Contract Plans: This stage involves the survey of the location on the ground with determination of earth volumes and other data needed for final plans and estimates.

In 1954, Pryor expanded his original four stages to eight. The expansion of the original stages was largely to include work in new areas such as inventory and maintenance (28).

Design Stages and Photographic Scales Used by Design Agencies

Practice of the California Division of Highways

Rather than making use of stages, California divides photogrammetry for highway design into three

product classifications which are then suitable for various phases in design (14). The classifications and their uses are:

(1) Aerial photography: Contact prints are the basic products and are used as single prints, enlargements, or made into mosaics. Photography is taken at various scales varying from 2000 feet-per-inch to 200 feet-per-inch with the scale depending on the land use and the intensity of development. The smaller photography scales are adaptable to reconnaissance and preliminary study of various routes. Uses mentioned for contact prints are advanced planning and location studies, materials and foundation studies, determination of drainage areas, supplementing topographic maps, and to gain a knowledge of topographic and cultural detail.

Enlargements up to six diameters are used. They are suited for right-of-way estimates, interchange studies, and study of set backs. The enlargements are often printed on

film so that ozalid prints can be made in quantity at low cost.

Mosaics are used primarily in planning studies and are also good for project reports and public meetings. Figure 3 is representative of a mosaic used for route studies.

(2) Reconnaissance mapping: is used primarily for location studies. It is of particular value when one or more routes are studied and excavation quantities are an important cost factor and grade is a determining factor. The use of U. S. Geological Quadrangle sheets is recommended whenever they are available. When topographic sheets are not available photogrammetric mapping with photographs of from 800 feet-per-inch to 1600 feet-per-inch are recommended with the smaller scales being used for the more rugged terrain. A reconnaissance map of this type is shown in Figure 4.

(3) Design mapping: This step is now being used by California to substitute for the final location survey. The steps suggested for these maps are photography, control surveys and map compilation. This process is often used to prepare complete construction plans and acquire right-of-way. This method of design necessitates very little field surveying. Figure 5 is an example of a map plotted for design purposes.

Practice of Ohio Department of Highways

Ohio has adopted a new method of design which is intended to make a great deal of use of photogrammetry and electronic

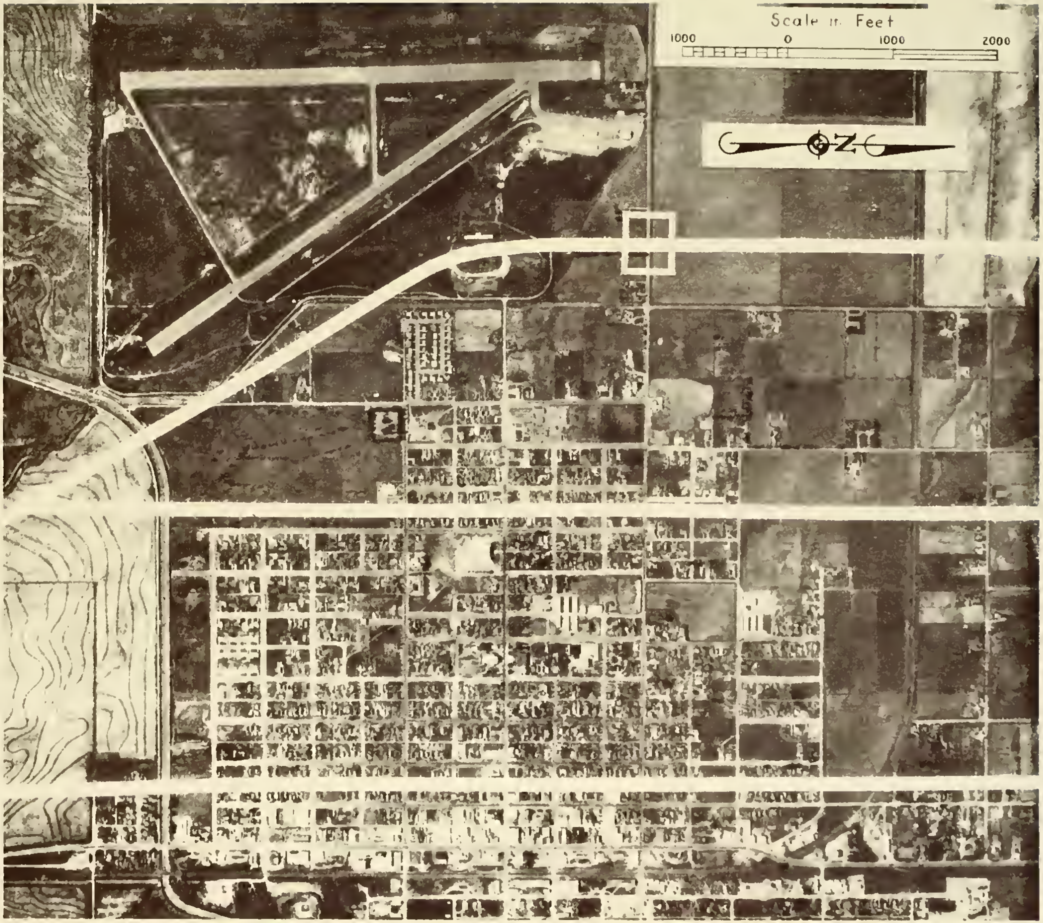


FIG. 3 MOSAIC FOR RECONNAISSANCE STUDY OF ALTERNATE ROUTES

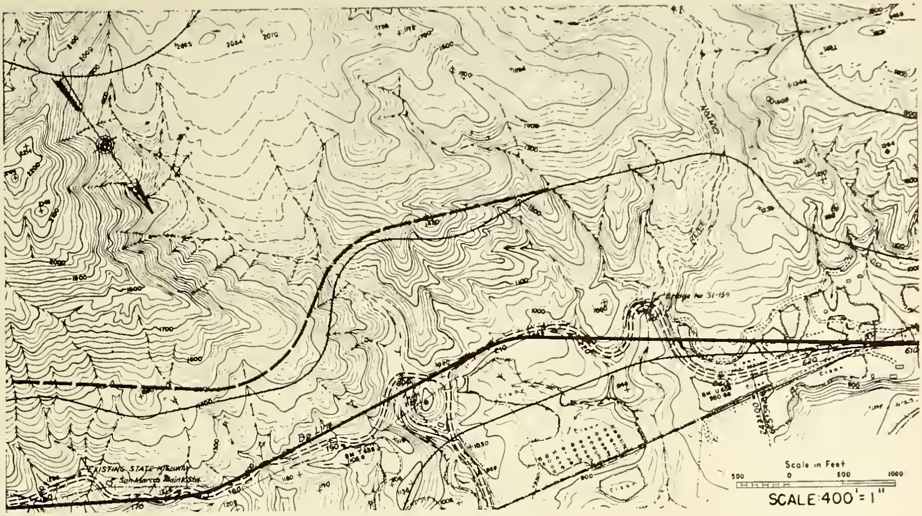


FIG. 4 PHOTOGRAMMETRIC RECONNAISSANCE MAP

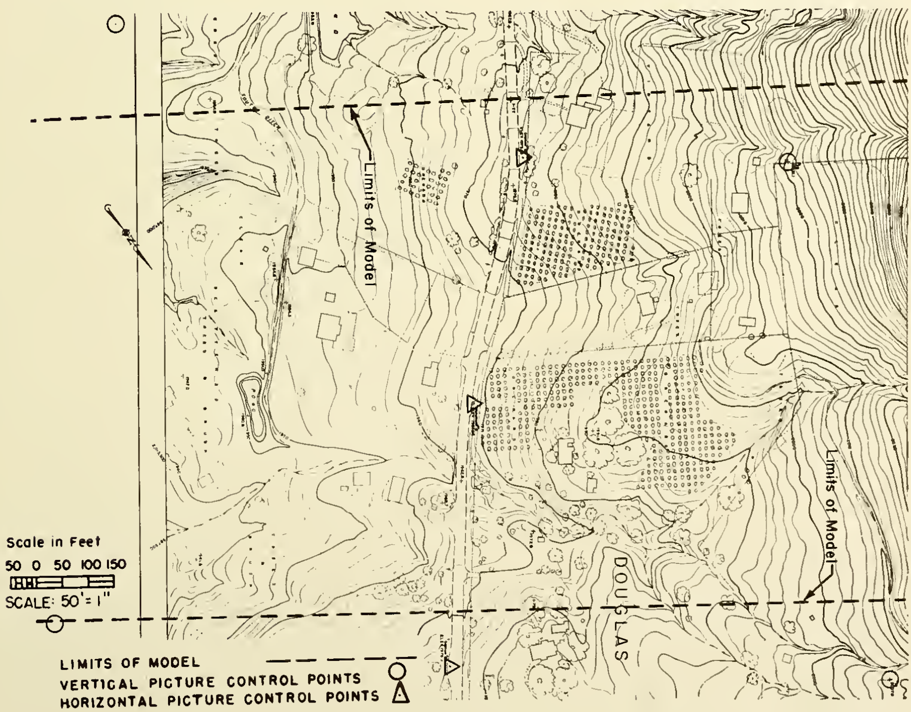


FIG. 5 PHOTOGRAMMETRIC DESIGN MAP

computation and which it hopes will eliminate 40 percent of manpower now used in conventional design studies (30). Steps used in the Ohio process are:

(1) Study of Route: By using existing U. S. Geological Survey ten and twenty foot contour maps one or two strips of suitable terrain are selected for further study.

(2) Survey of Control and High Level Photography: The selected strips are photographed from 6,600 feet to produce photographs at a scale of 800 feet-per-inch. Ground survey control is also established for plotting the photography. Extensive use of theodolite and suttense bars are used to speed up the surveying.

(3) Plotting of Preliminary Map: Use is made of the Kelsh plotter to produce maps at 200 feet-per-inch from the 800 feet-per-inch photography. These maps are then used to establish tentative grades and alignment. Spirals and horizontal curves are plotted on this map and rough earthwork quantities are calculated with the aid of an electronic computer.

(4) Survey of Center Line: The alignment selected in the previous step is then surveyed in the field. Property line ties are made and picture point elevations are taken and marked on the ground with muslin or linen.

(5) Low Level Photography: The new center line is photographed again from about 1650 feet in altitude to produce 200 feet-per-inch photography.

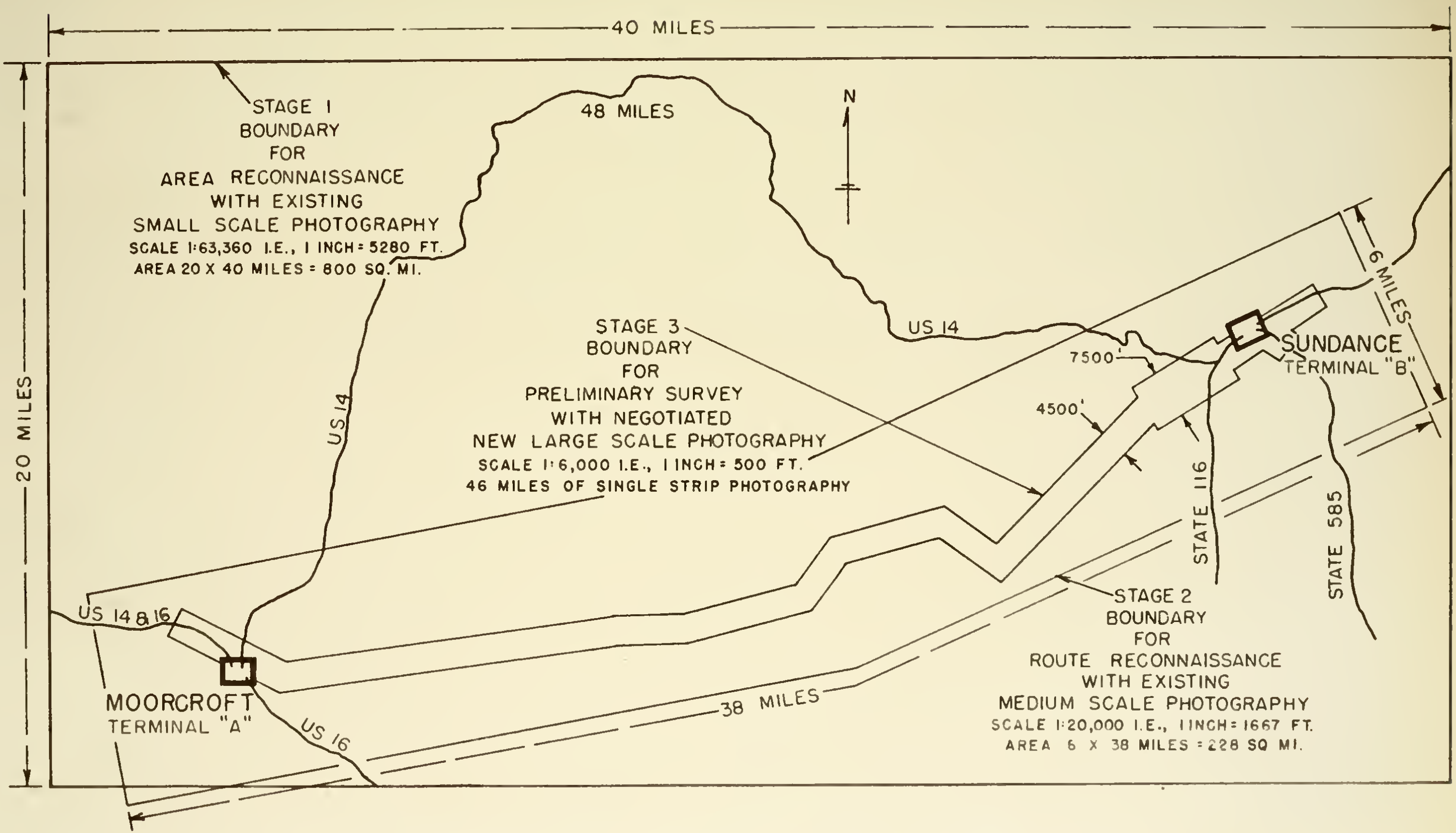
(6) Design Mapping: A planimetric map at 50 feet-per-inch is made for the route from the large scale photographs with sometimes a 20 feet-per-inch map being made by enlargement for bridges and interchanges.

(7) Automatic Designing: With the large scale photography and a plotter equipped with a horizontal and vertical measuring device cross sections are punched onto standard electronic computer cards. These cards are then fed to an electronic computer which calculates cross sectional areas, earth volumes, slope stake positions, prints cross sectional shapes with the aid of an electron tube screen, and summarizes design data and prints it so that it can be used for contract plans.

Practice of Wyoming State Highway Department

Wyoming recommends that especially on large projects that highway location work be divided into four stages (31). The four stages as shown in Figure 6 are:

(1) Area Reconnaissance: This stage is used to identify the best route bands for further study. In this stage existing photography of around 5280 feet-per-inch could be used. They recommend a band width of from 40 to 60 percent of the band length to be studied. They also recommend the use of stereo mosaics for selecting routes. This stage also helps to select control points and alternate routes for the next stage of study.



PHOTOGRAMMETRIC DESIGN STAGES FOR A WYOMING HIGHWAY

FIG. 6

(2) Route Reconnaissance: This stage is intended to be used to select the best route band. Medium Scale photography is recommended for this stage. The suggested scales for photographs are 1667 feet-per-inch. Aids suggested for study in this stage are enlargements, uncontrolled mosaics and stereo mosaics.

(3) Preliminary survey to secure positioning of the center line: For this stage it is recommended that photography be taken at 1000 feet-per-inch to make maps for design at 200 feet-per-inch. It is suggested that the design of some of the rural areas can be accomplished with the reconnaissance stage photography. However for most cases 5 foot contours and 2½ foot contours are desired and to expedite this mapping, ground control should be carried out and targeted before preliminary photography is taken.

(4) The location survey step is carried out by the staking out of the center line, the completing of the final design and the securing of right-of-way data. The exact center line is positioned on the maps made in the preliminary survey and cross sectioning is done with the plotter and recorded using a punch card cross sectioning recorder. From the cross sections costs are developed and final design data determined.

Procedure Recommended by the

Massachusetts Institute of Technology

It is suggested that highway engineering be divided into four different phases as follows (23).

(a) Reconnaissance

(b) Preliminary

(c) Design and Location

(d) Relocation, Improvement and Maintenance

The types of products to be used in each of these phases are classified in three groups as follows: aerial photography, reconnaissance mapping and design mapping.

Aerial photographs include contact prints, enlargements, mosaics and color prints.

The three design phases are:

1. Reconnaissance Phase: Topographic maps can be used when they are suitable. Reconnaissance mapping should be done with contact prints whenever topographic mapping is not available or is out of date. Suggested scales for the reconnaissance stage are: 1:8000 down to 1:20,000.

Mosaics are suitable for this phase. These studies can be made to determine controlling points of various routes, stream crossings, ridge and valley locations, and rough estimates of structures needed per route. Color prints are sometimes helpful to analyze soil and study materials.

2. Preliminary Phase: There are numerous items listed as belonging to this phase, some of the important ones are: rough determination of control point elevations, calculation of drainage areas, selection of bridge sites, soil and rock types and conditions, building and tree obstructions, right-of-way determinations and selection of final design mapping sites.

3. Design and Location Phase: In this phase a large scale map is used of a strip of terrain 300 feet to as much as 2000 feet wide. Design mapping is usually done with a 6-inch lense or sometimes an $8\frac{1}{4}$-inch lense where trees are dense. Photographs for design are usually taken at scales varying from 200 feet-per-inch down to 800 feet-per-inch. Recommended scales vary from 25 feet-per-inch up to 100 feet-per-inch with corresponding contour intervals of from one half to five feet. It is also recommended that control of second order accuracy be used and that a system of state plane coordinates be used. This map is then used to develop an alignment with all details designed to fit the map such as curves, grades, positions of P.I.'s and V.P.I.'s. The complete design and costs can be calculated by taking cross sections and the development of a mass diagram.

Design Stages and Photogrammetric Product Considered Suitable for the Knobstone Escarpment Problem

As the title of this project indicates the work for this project was to be of reconnaissance and preliminary design nature. This was decided upon because the photography available was of intermediate scale and not suitable for a final design map. A final design step in view of the rugged topography would require additional coverage at a very large scale.

The three stages to be used for this project are:

1. Reconnaissance of an Area.
2. The Preliminary Analysis of Alternate Routes.

3. Final Location and Design.

(1) Reconnaissance of an Area: The State Highway Department of Indiana has been interested in finding a good crossing of the Knobstone Escarpment for a long time, even before the advent of the Interstate System. They have studied their own lines, topographic maps, available airphoto coverage, and investigated the area extensively in the field. Because the State Highway Department had studied the area thoroughly the band of terrain for reconnaissance study was considerably narrowed down. The author felt it necessary to go over the recconnaissance stage to become familiar with the area through the use of all available aids. Several field trips were made into the area. Maps from New Albany were obtained, also United States Geological Survey (U. S. G. S.) maps and notes were obtained. U. S. Department of Agriculture aerial photographs and mosaics of Floyd County were obtained, United States Coast and Geodetic Survey 7½-minute quadrangle sheets were obtained for New Albany and Georgetown. Indiana State Highway Department highway and traffic maps were obtained for study. The two flight lines photographed for the highway department were studied and prints ordered for the escarpment section. Also an ozalid print of the flight lines was obtained. The position of the preliminary stage photography was outlined on a quadrangle sheet.

(2) The Preliminary Analysis of Alternate Routes:

The first step in this process after the outlining of the band of terrain on the quadrangle sheets which was photographed for preliminary mapping, was to photograph that portion of the quadrangle sheets and enlarge it to the same scale as the contact prints.

A semi-controlled mosaic at 800 feet-per-inch was also obtained from the State Highway Department of Indiana with one route marked on the mosaic which the highway department had selected for study. With the aid of the contact prints and mosaic, several routes were marked on the enlarged section of the quadrangle sheet as possible routes for study. Because these trial routes were so scattered on the band of terrain, it was decided to map the entire width of the two flight lines across the escarpment with the Kelsh plotter. Also because of the ruggedness of the terrain, it was felt that mapping with the Kelsh would give a more detailed map at 200 feet-per-inch than the enlarged quadrangle sheet at 800 feet-per-inch. An area 20,000 feet long and 12,000 feet wide with 10 foot contours and a scale of 200 feet-per-inch was thought to be suitable for preliminary design in the escarpment area. It was felt that the preliminary design should give some rough estimates of the cost that might be expected for each of two or three alternate routes. One of these designs could then be refined for a final design.

(3) Final Location and Design: Even though no attempt will be made in this project to decide on a final location,

the author feels that some of the considerations for a final design must be fixed in order not to overlap with the preliminary design. Based on all the preliminary design data available one of the preliminary designs would be selected and then further investigated and necessary adjustments would be made to improve grades, alignment and costs. Data such as rock profiles should be considered, consideration be given to varying elevations of the two pavement centerlines especially in narrow cuts and on long grades. The final location could be carried out in two ways. The first would be by the conventional means of surveying the center line and cross sections and slope staking. The second method would be a continuation of the photogrammetric process. This would entail the reflying of the proposed route at a larger scale with maps being produced from this photography at a scale of 40 or 50 feet-per-inch and with 2-foot contours. This map would give accurate enough information for grade and earthwork calculations and then only the construction survey would be necessary.

CHAPTER III

TYPES OF PHOTOGRAMMETRIC PLOTTERS USED IN MAPPING PROCESSES

Introduction

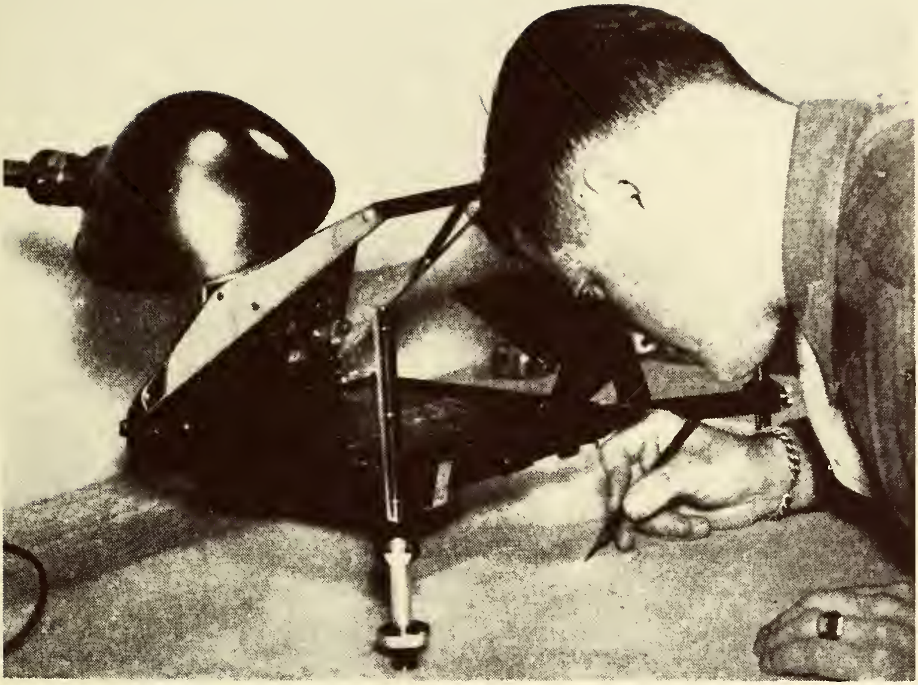
Before describing the Kelsh plotter which was used for this research project a description of types and classes of plotters presently being used for various purposes may be helpful.

Over the past 30 or so years, there has been a multitude of attempts made to develop a mechanical or automatic device which would produce reliable maps from aerial photographs. Many of these mechanical plotters were designed for a specific use or type of camera and did not come into general use; however, out of these many attempts there has emerged four types which have been used extensively (20).

Four Basic Types of Photogrammetric Plotters

Single Photograph Plotting Instrument

The single photograph plotter, as its name indicates, is monocular or non-stereoscopic. These plotters are very simple in design and may or may not use lenses or optical devices for plotting. The sketchmaster type as shown in Figure 7 does use a lense and a semi-opaque mirror. In mapping with the sketchmaster, the viewer can by means of its



AERO SERVICE CORPORATION
VERTICAL SKETCHMASTER

FIG. 7

mirror, see the photograph and the map manuscript simultaneously and sketch planimetric detail on the manuscript. Small corrections of scale and tilt can be made by adjustment of the sketchmaster's three legs. Interchangeable lenses are provided for plotting at other than 1:1 ratios. The sketchmaster is used to plot planimetry and is of no use in taking vertical measurements.

Another type of single photograph instrument is the reflecting projector plotter. The reflecting projector uses a light source and lenses to project a photograph onto the map manuscript. The reflecting projector is better adapted than the sketchmaster to making scale, tip and tilt connections.

Some makes of sketchmasters are the Vertical Sketchmaster, Rectoplanagraph Oblique Sketchmaster, and Universal Sketchmaster. Some makes of projectors are the vertical reflecting projector and the Autofocus vertical reflecting projector (20).

Sketchmasters and reflecting projectors are not used in accurate mapping processes but are applicable to making of uncontrolled sketch maps.

Stereometer Type Plotter

The stereometer type plotting instrument is a comparatively light, simple, and low cost machine. It essentially consists of a simple lense or mirror sterescope, a measuring device which is made up of two floating marks and a micrometer to measure the changes of distance between the two floating

marks, a holder and alignment mechanism consisting of a standard mechanical drafting arm, and a drawing mechanism with a lead holder attached to an arm. This machine measures difference of elevation by measuring absolute parallax which can be converted to differences of elevation in feet.

The common makes of this machine are the Abrams Contour Finder as illustrated in Figure 8 and the Fairchild Stereo-comparagraph. The ordinary device of this kind cannot eliminate tilt and tip but the use of rectified photographs will increase its accuracy.

Several machines have been developed which in addition to the simple contour finder principle have photo holders which can be adjusted to simulate the tip, tilt, and altitude differences. Two makes of this type of plotter are the Wernstedt-Mahan Plotter and the KEK Plotter.

Stereometer types of plotters are not used much for mapping of a large area but are useful for single photograph studies. If the area studied is much larger than one or two pictures their use is limited. They are slow to operate and not reliable unless abundant control is available to use in a datum plane correction graph. The correction graph is necessary to correct for lense distortion, tilt, film distortion and variations in flight altitude. The stereometer is useful though to measure the heights of objects and draw simple form lines. The normal range of the ratio of flight height to the contour interval that can be plotted to accuracy requirements (C-factor) varies from 250 to 350.

ABRAMS CONTOUR FINDER

(1) Stereoscope
(2) Measuring Unit
(3) Pencil arm
(4) Lighting Unit
(5) Alignment mechanism
(6) Photogrammetric computer
(7) Carrying case

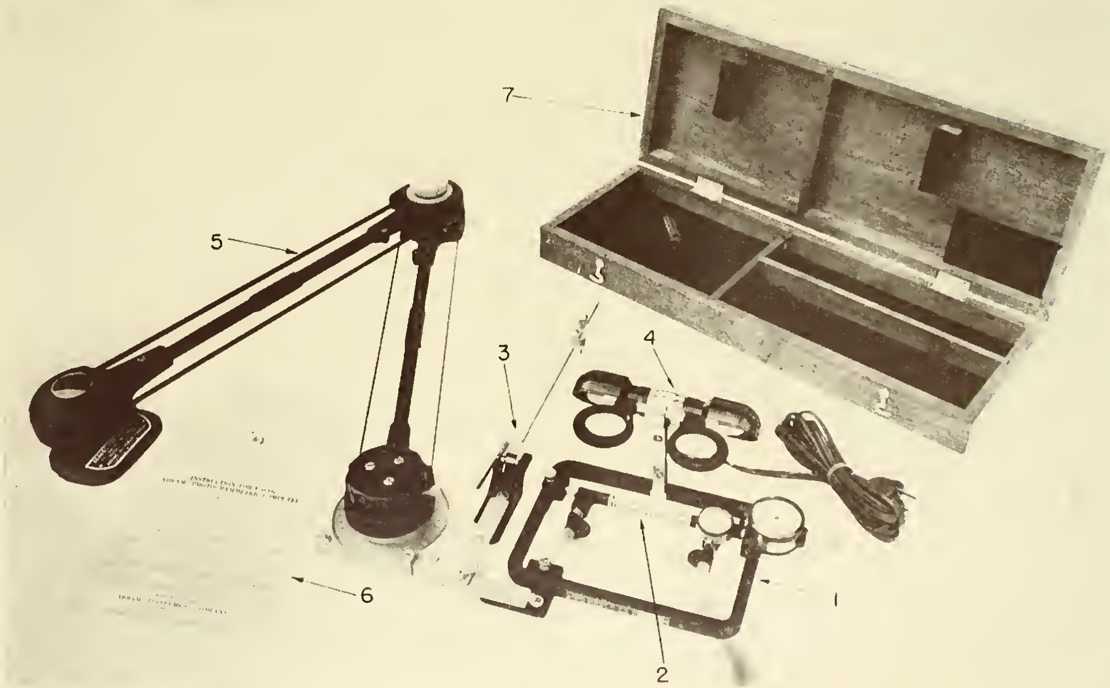


FIG. 8

Double Projection Stereoplotters

The double projection plotter uses direct optical projection. Two rays of light from projector lamps are passed through sterioscopic diapositive photographic plates and lenses to produce a real optical model. The optical model is produced when the source light of two complimentary colors is reflected from a white reflecting surface and then viewed through filters (glasses) which separate the two colors of light. This plotter has five basic functional components namely: (a) a projection system; (b) an orientation system; (c) a viewing system; (d) a measuring system; and (e) a plotting system. These plotters are generally designed for one or two focal lengths of photography; usually vertical photography. The basic objectives in the construction of the double stereoplotters were simplicity and low cost.

Double projection plotters usually are made distortion compensating by one of three methods. These methods are: (1) By using a projector lense with compensating distortion; (2) By the use of asymmetric ball cams which change the distance from the projector lense to the diapositive plane; (3) By using diapositives printed with a correcting printer. Some of the common makes of double projection stereoplotters are: Kelsh Plotter, Balplex Plotter, Nistri Photomapper, and the Multiplex.

The double projection stereoplotters such as the Kelsh and Balplex are used extensively for small scale and large

scale mapping. Neither of these machines is able to bridge control reliably or quickly and therefore they require extensive control for large area mapping. Therefore on large area projects they are used in conjunction with the Universal type first order machines. These plotters however are particularly suited to smaller projects or mapping in areas where surveying has to be carried out in any case as in highway construction. Except for the Multiplex, which really is a series of double projection stereoplotters, this type of plotter is incapable of accurate or easily executed aerotriangulation.

The "C-factor" for double projection stereoplotter varies from 600 to 1000. Enlargement varies from $2\frac{1}{2}$ to 5 diameters for map manuscript over the original photographs.

Universal Type Plotters

A universal plotter is one that is capable of very high accuracy and is capable of plotting from many types and sizes of photographs and photographs taken at different altitudes all the way from the horizontal terrestrial type through different obliques to various vertical photographs. Universal plotters are generally capable of accurate aerotriangulation. The universal plotters are usually classified as first, second and third order machines according to the accuracy of the plotting system. The first order machines are designed to recreate mathematically a stereomodel of the highest accuracy. A second order machine is similar to a first order

machine except that it is simpler in design and is only one third as accurate in terms of spot elevation accuracy. A third order machine makes use of an approximate instead of a mathematically correct recreation of the stereomodel. The third order machines too are of still simpler design. Examples of Universal Plotters are: Wild Autograph, Zeiss Stereoplanigraph, Nistri Photostereograph and the Galileo-Santoni Stereocartograph (20). Figure 9 shows a universal type plotter.

First order universal plotters are usually only used by a large mapping organization because of their great cost. Also to be efficiently used they are best employed in conjunction with a team of plotters of lower order. In such an organization they can be economically employed on aerotriangulation work by which means additional control can be measured for use by the lower order plotting instruments. The use of the first order plotter for control extensions can effect great economies by cutting down on costly field surveys and can increase accuracy of the mapping unit by taking more and better situated control data than might be obtainable in the field. The first order plotter too is ideally suited to making very accurate large scale maps such as might be needed in city mapping. The first order machines give much more accurate work because of their more precise construction and greater power of magnification. The greater power of magnification compounds the machines accuracy because then they can use smaller scale photographs and this means

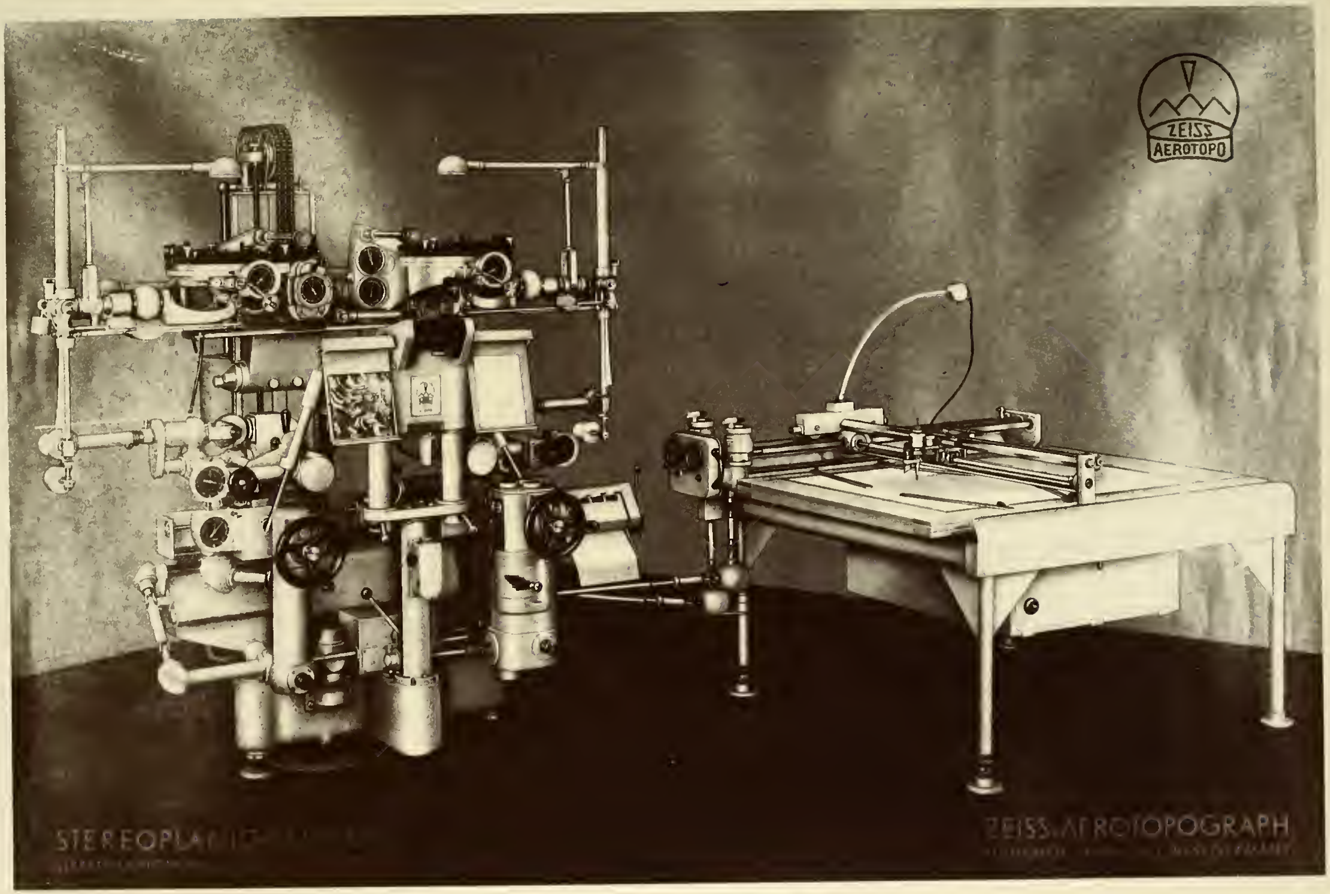


FIG. 9 FIRST ORDER UNIVERSAL STEREOPLOTTER AND AEROTRIANGULATION INSTRUMENT

the planes taking the photographs are able to fly at higher altitudes which results in a better quality photograph because of greater stability of planes at higher altitudes. First order plotters have a photograph to map manuscript magnification powers of from 7 to 24. In order not to use the machine at its limit, a specification often used is a maximum enlargement of 8 times the photograph scale. First order machines have a C-factor of from 900 - 2000.

Considerations in the Selection of a Suitable Type of Plotter

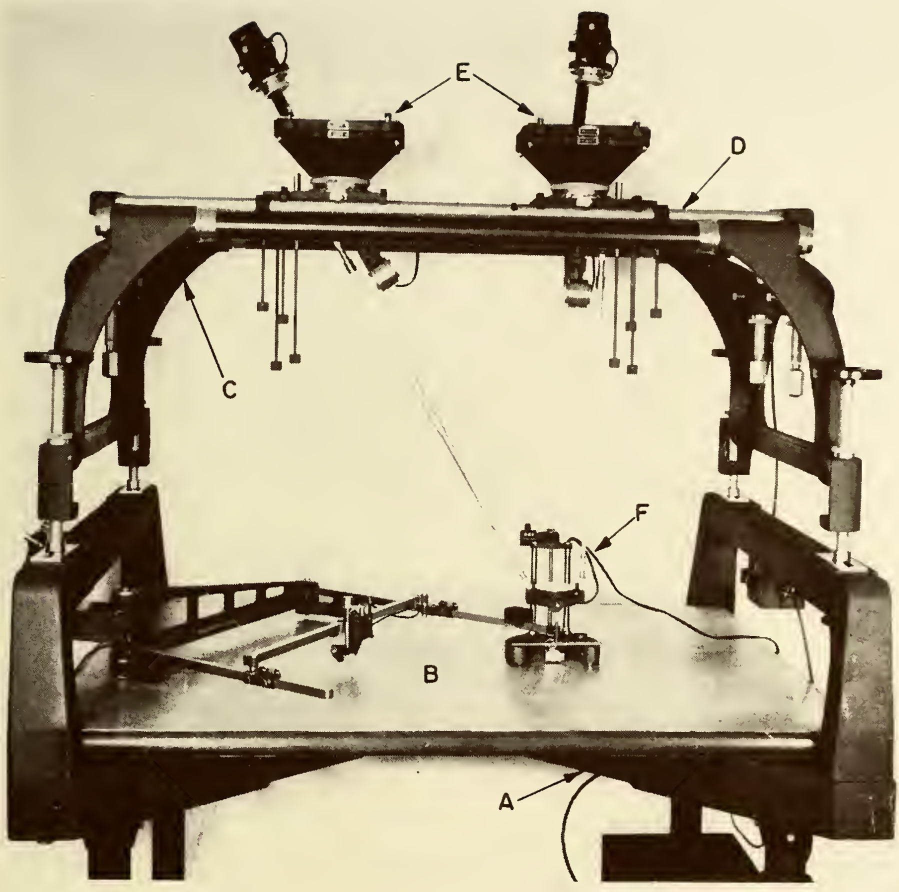
The various types and makes of plotters by virtue of their design and from experience in their use have been found suitable and most applicable to perform one or perhaps several types of plotting in the mapping process. In selecting a suitable plotter to perform a mapping function, consideration should be taken of the accuracy of the work desired, adaptability to plotting from differing sizes of photographs, the amount of work to be performed, the skill required for plotting and orientation, magnification or reduction that can be made, the quality and quantity of control available, and the contour plotting accuracy of the machine.

The contour plotting capabilities of the machine is usually expressed as a ratio of average contour interval that can be plotted within accuracy limits to the flying height in feet. This ratio is usually called the instrument's C-factor. The plotting of contours usually is the critical part of the mapping process.

The power of magnification, commonly called the enlargement ratio, of any instrument determines the optimum number of times that map manuscript scale may be larger than the scale of the aerial photographs. This machine characteristic is very important in determining the contour interval and scale to be used in plotting (35). Consideration of proper balance between the C-factor and the enlargement ratio is necessary to obtain efficient use of photogrammetric plotting instruments.

Kelsh Double Projection Stereoplotter

The Kelsh plotter has the unique feature of having a distortion compensation system which is readily adaptable to common types of aerial photography. The two projectors use the same lense as the aerial camera and compensate for any radial lense distortion by means of mounting the lenses with a system of spherical cams. These cams raise and lower the lense minute amounts according to calculations based on the lense's calibrated distortion characteristics in such amounts as to compensate for the radial distortion characteristic of the lense. The cams are automatically positioned for the portion of the model viewed because they are linked to the light guide rods which follow the tracing table in its motion across the map manuscript. It is possible to use 8¼ inch focal length, 6 inch focal length of several makes and 11.5 cm focal length lenses as they are designed to be interchangeable in a lense mounting assembly. Figure 10 shows the Kelsh plotter's general structure and Figure 11 shows



A = TABLE FRAME

B = SLATE TABLE TOP

C = SUPPORTING TRUSS AND FRAME

D = PROJECTOR TRACK FRAME

E = PROJECTOR ASSEMBLIES

F = TRACING TABLE

FIG. 10 KELSH DOUBLE PROJECTION STEREOPLOTTER

the lense assembly. The parts of the Kelsh plotter are listed as follows:

A. The Table Frame. The frame consists of a heavy X-frame with two inverted U-sections attached to either end of the X-sections. This rigid frame is supported on four pipe legs which have built-in adjustable foot screws to level the X-frame.

B. The Table. The table consists of a seasoned slab of slate weighing about 750 pounds which has been machined so that it does not deviate from a plane surface more than 0.002 inches. This slate can be leveled precisely by means of four set screws threaded into the top of the X-frame. This top must be accurately leveled because it serves as a reference plane for vertical measurements.

C. The Supporting Frame. The supporting frame consists of two end trusses rigidly tied together with two spacing bars. The supporting frame rests on four adjustable clamping screw legs which are seated in four slots in the inverted U-members, and is capable of being raised or lowered and moved sideways. The supporting frame also has three long supporting screws projecting upward to support the projector track frame.

D. The Projector Track Frame. This frame is made up of two parallel bars 56 inches long which are tied together at each end rigidly. One bar is square and one is round. These bars serve as a track for positioning the two projectors.

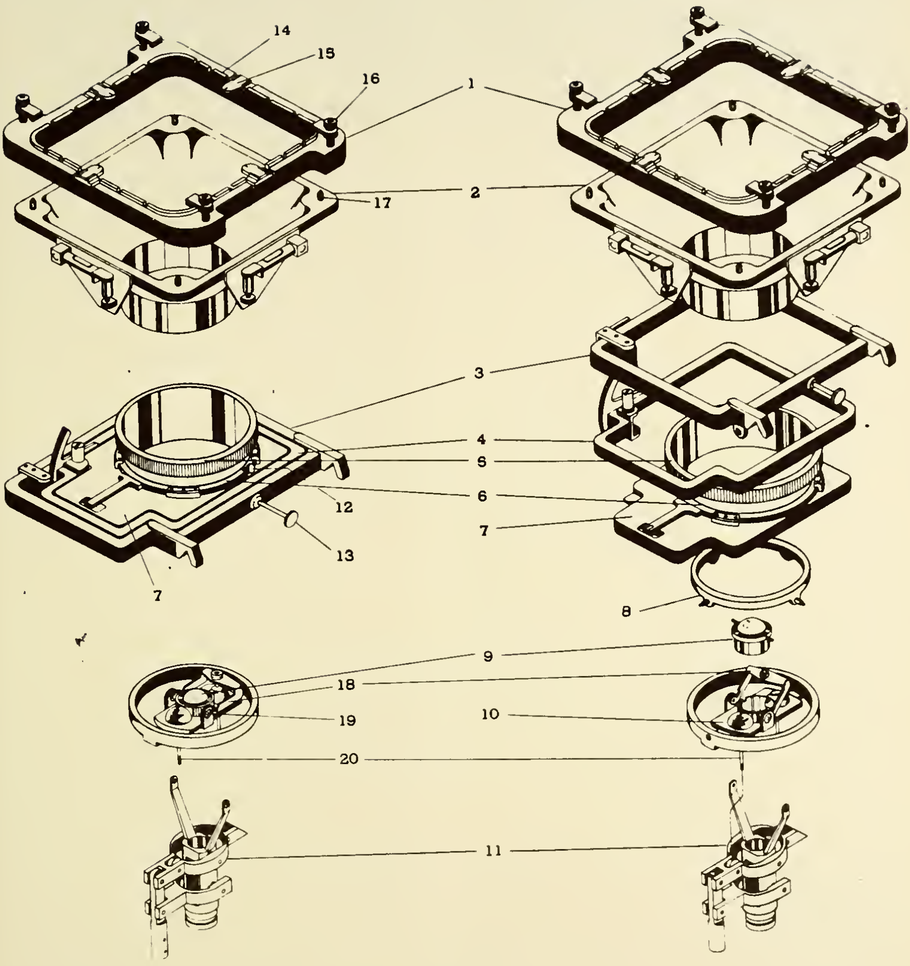


FIG. 11

KELSH PLOTTER PROJECTOR ASSEMBLY

E. The Projectors. Figure 11 shows an assembly view of the projector and its base. The parts are:

1. glass diapositive plate holders.
2. the projector cone (either 6-inch or $8\frac{1}{4}$-inch focal length) with level bubbles.
3. the projector base and X-tilt carriage. It sits with the two V-notches resting on the round bar and a bearing roller rides on the square bar.
4. the Y-tilt plate.
5. the principal distance ring which can be raised and lowered by means of its screw thread to give an exact setting of the calibrated principal distance of the various cameras.
6. the swing adjustment ring.
7. the X-tilt plate.
8. the gimbal ring.
9. the lense.
10. the lense mount assembly.
11. the yoke connector which is used to suspend the guide rods from the lense.
12. swing motion clamp screw.
13. the limited y-motion screw.
14. a machined boss for accurate seating of the plates.

15. transparent marks for centering glass diapositives by their fudicial marks.
16. glass plate holder clamp lugs.
17. conical pointed plate holder positioning screws.
18. the lense lifter bracket.
19. a bearing hinge for the cam lifter.
20. the cam link and guide rod assembly.

The Kelsh plotter's components can be divided into five functional systems. A brief description of these components will make it easier to understand the plotter's operation.

A. The Projection System. The Kelsh uses two projectors which are designed to simulate the taking cameras. For best results the projector's lenses should be identical to the camera's. The projector's focal length is adjusted to duplicate that of the camera. Each projector is so mounted that it can be rotated about a longitudinal, transverse, and vertical axis. These motions are generally called X- and Y-tilt and swing. The projectors are capable of large X-motions, a small amount of Y-motion and sometimes they are equipped with a Z-motion. The projectors accommodate 9- by 9-inch glass diapositives which are held by plate holders at the correct distance from the lense.

B. The Orientation System. The orientation is carried out in two steps - relative orientation and absolute orientation. Relative orientation consists of positioning one

projector with respect to the other such that the projected image forms a clear model free from parallax. When this is accomplished, it indicates that the two projectors are in the same position with respect to each other as the plane was in at the time of exposure. Relative orientation is achieved by using the X-tilt, Y-tilt and swing adjustments as shown in Figure 12. The X-tilt corresponds to a wing up position, the Y-tilt corresponds to a climbing or diving altitude of the plane and the swing movement reproduces a crabbing or drifting attitude of the plane.

Absolute orientation consists of setting the model level with respect to sea level datum and also setting the model to a definite scale. The leveling process is accomplished by adjusting the three point suspension of the projector track frame, until height readings on the tracing table agree with elevations taken in the field.

After the model has been set level the scale adjustment with four to five diameter enlargement can be accomplished by changing the base to height ratio, which means spreading the projectors apart or bringing them closer together on the parallel bars until the distance scaled between two objects observed in the model agrees with a distance previously measured between the same objects in the field.

C. The Viewing System. The Kelsh plotter makes use of an anaglyphical system. Two lamps, each aimed by the guide rods from the tracing table, project a narrow beam of light through the glass diapositives and lenses onto a moveable

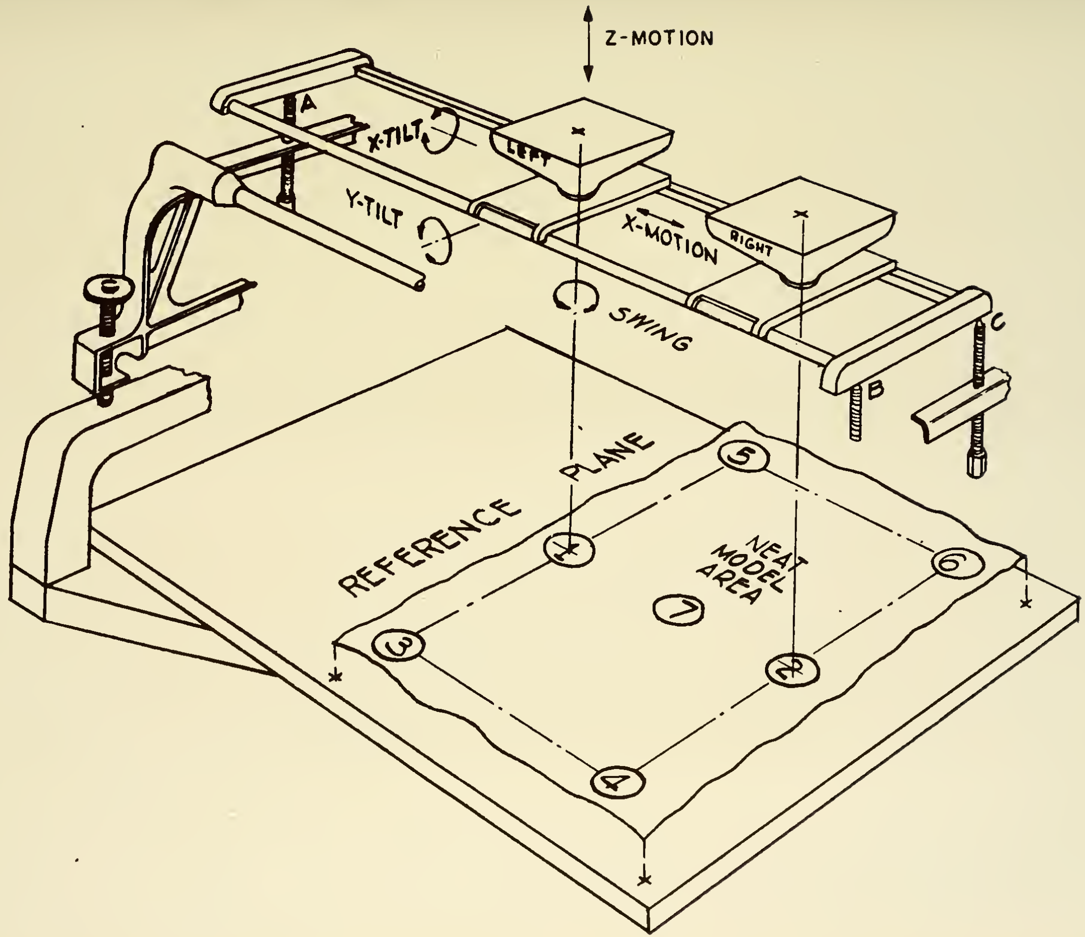


FIG. 12 KELSH PLOTTER ORIENTATION POINTS AND MOTIONS

platen which is attached to the tracing table. The platen is a perfectly white reflecting surface about 3½ inches in diameter. The tracing table is moved around on the top of the map surface on top of the slate. The platen is raised and lowered to focus the model so that the observer can, by looking through glasses with lenses corresponding to the complimentary beams of light, see the model in the third dimension. The intensity of the light rays can be adjusted to suit the observer's eyes by the use of rheostate mounted near the observer's hands.

D. The Measuring System. Vertical measurements are made with the tracing table as all horizontal measurements are fixed orthographically. To make it possible to read vertical elevations or set them for plotting contours, use is made of a floating dot which is a method of measuring obsolute parallax in a stereoscopic model. The floating dot is built into the platen by means of a small point of light. This dot of light can be raised and lowered by turning a threaded shaft which lowers and raises the platen. By means of accurate calibration, turns of the shaft have been converted to differences in elevation in feet or meters. To read an elevation of a point on a model after relative and obsolute orientation, the observer raises or lowers the platen so that the floating dot comes to rest at the point of which it is desired to read the elevation. If the floating point had been indexed on a point of known elevation, the

elevation of the new point is read directly from the dial geared to the threaded shaft.

Horizontal distances can be measured by setting the dot on the ground at the two points between which the distance is to be measured. The pencil on the tracing table is located vertically below the floating dot and so a mark can be made on the map by the pencil at any number of desired points. The distance then can be scaled directly from the two points on the map.

E. The Plotting System. The slate slab serves as the mapping surface and the paper is placed directly on the slate. The tracing table is then operated on top of the map manuscript. As the tracing table is moved about, the pencil lead which can be raised and lowered can be made to mark the mapping paper. This pencil point is positioned so that it always gives a true orthographic projection of the position of the floating dot. Some plotters are equipped with pantographs to give a reduced or enlarged map scale with respect to model scale.

Plotting Preparation and Orientation Procedure(48)

Before describing the model orientation a brief list of the steps in preparation for plotting is as follows:

1. Check the diapositives for marks and breakage.
2. Assemble the correct lense and projector in the projector bases.

3. Adjust the principle distance ring to the calebrated focal length of the camera.
4. Insert the proper set of gears in the plotting table for the scale ratio being used.
5. Check the projector lights for focusing and eliminating dark spots.
6. Check the level of the slate table top.
7. Check the pencil point to see if it is below the center of the tracing table.

To set up a stereoscopic model in the plotter two consecutive glass plates (having 50-60 percent overlap) from a flight line are placed in their respective plate holders on the top of the projectors. The interior orientation procedure necessary to set up a parallax free model is a trial and error process and depends for its degree of precision on the ability of the operator. Figure 12 shows the model area and projector motions that are used for orientation.

The author used what is called the rational method of orientation. After the glass diapositives are put in place there will appear a red and blue image of the same picture points. They will not at first be in juxtoposition until the two projectors are oriented. The first step is swing correction. First observing the center of the model point (7) both projectors are rotated about their vertical or Z axis to as close an orientation as possible, then swing is further adjusted while viewing the model at points (1) and

(2) until no greater orientation is possible. Then working on either side, for example the left side, the observer using color separation notices whether the color separation at point (5) and (3) is symmetrical with respect to the X-axis. If the color separation is symmetrical a Y-tilt motion will correct the separation. The process of swing correction at (7), swing correction at (1) and (2), X- and Y-tilt at (3) and (5) are carried on consecutively first by observing color separation and then with glasses observing floating dot separation until a parallax free model is observed.

Absolute orientation of the leveling procedure is carried through using the three screws, A, B and C which support the projector track frame. Leveling is first carried out in the Y-direction by adjusting screws B and C and then in the X direction using adjusting screw A. The observer, using picture points of known elevation, takes elevation readings at these points with the floating dot of the tracing table as the measuring mark. For Y-leveling there should be two points on opposite sides of the table near (5) or (6) and (3) or (4). X-leveling uses picture points preferably near points (1) and (2). When the model has been leveled satisfactorily in both directions, it is then ready for scaling. Scaling is accomplished by measuring the distance between model image points and comparing them to distances measured on the ground or obtained through triangulation in the field. If there is more than one distance available,

checks should be made of all the lines and if there are slight discrepancies an average scale should be used. Scaling does not affect the leveling or Y-parallax as it is accomplished by small amounts of X-motion of one projector. However, after scaling it may be necessary to raise or lower the upper supporting frame in order that the tracing table platen be centered in its motion on the tracing table. Leveling will have to be checked over again and the parallax should be checked before plotting commences.

Before plotting is commenced, the area to be plotted should be outlined because the flight lines overlap sideways and have more than 50 percent overlap. If all of each model were plotted in each case there would be about 20 percent duplication of plotting effort over a series of models. By assembling the photographs to be plotted into a mosaic the amount of overlap of models can be marked so that it can be equally divided between each model. The area then plotted need only exceed this effective model area by just enough to be able to join the models together with picture pass points.

CHAPTER IV

RECONNAISSANCE OF THE KNOBSTONE ESCARPMENT AREA

Introduction

The Knobstone escarpment at New Albany, Indiana, was selected for this project at the suggestion of the Joint Highway Research Project who had been authorized by the State Highway Department to purchase a Kelsh Plotter for research projects at Purdue University. It was felt that this location offered the greatest challenge in the area of photogrammetric plotting because there exists in the escarpment the greatest amount of local relief to be found anywhere in the state. Another reason for selecting this area was the possibility of assisting the state in the selection of a highway route through this area which has always been a bottleneck in the transportation network of the state.

Relation of the Route to the Interstate Highway System

Interstate Highway #64 which crosses Indiana west to east is a new highway which will run from St. Louis, Missouri, to Richmond, Virginia. In Indiana, this highway extends from the general area of Vincennes to the Ohio River at Louisville as shown on Plate 1. . Before crossing the river into Louisville, this highway must descend the escarpment

in the vicinity of New Albany. Interstate Highway #64 is part of a nationwide 41,000 mile system of limited access, high speed freeways to be built during the next 15 years. The nationwide Interstate system is shown in Figure 1.

Existing Transportation Routes

At present there is a railway and three main roads and several local roads crossing the escarpment immediately to the west of New Albany.

The Southern Railway line running west to Illinois crosses the escarpment with the aid of a tunnel about 4000 feet long. This enables the railway to ascend from the 450 foot level of the Ohio valley to the 830 foot level of the Norman Upland without having to rise to the 920 foot level of the escarpment.

The Corydon Pike or State Route 62 follows the same general route as the Southern Railway but climbs to the top of the escarpment before descending into the Ohio valley. In this descent it drops from the 925 foot level to the 600 foot level in a distance of about 7000 feet and in this section has an average grade of about 5 percent combined with curves as sharp as 35 degrees. This alignment does not meet Interstate Standards especially when it is considered that in addition to carrying the traffic of Route 64 it has funnelled into it at the top of the escarpment the traffic of State Route 64 and U.S. Route 460.

The "Old Vincennes Road" which crosses the escarpment about a mile and a half north of Route 64 has an even lower standard of alignment. From the 920 foot level at the top of the escarpment the road descends to the 580 foot level in about 5500 feet of road. This drop results in an average grade of 8 percent with short pitches of 10 percent and has curves as sharp as 25 degrees.

The present Route U.S. 150 known as the Paoli Pike has been designated Interstate Route #64. This road has served as the main route for traffic proceeding to or from the west of New Albany. This route in ascending the escarpment has an average grade of 6 percent with short grades up to 10 percent. There are curves as sharp as 72 degrees and curves of 20 to 30 degrees are numerous. The truck traffic which travels this route has to travel at an extremely slow speed and a low cost truck climbing lane was added in 1952 to relieve the congestion.

There are other rural roads in the escarpment area but they are usually so steep that generally the local residents only use them for descending and the better roads are used to ascend the escarpment.

Figure 13 shows the Paoli Pike, Old Vincennes Road, and some of the local roads in the escarpment area.

FIG. 13

TOPOGRAPHIC MAP OF KNOBSTONE ESCARPMENT
From U.S. Geological Survey
New Albany 7½ Minute Quadrangle Sheet

Physical Features of the Knobstone Escarpment

Physiography

According to Lobeck's physiographic divisions of North America, the Knobstone Escarpment forms the boundary between the Till Plains division of the Central Lowlands province on the east and the Highland Rim division of the Interior Low Plateau province on the west. The Knobstone is the most prominent of a series of eastward facing escarpments running north-south in Indiana. The Cincinnati Arch uplift in the southeast corner of Indiana combined with the subsidence of the southwest corner of the state, which is a part of the Illinois Basin, has resulted in a general dipping of the bedrock to the southwest toward the Illinois basin at the rate of approximately twenty feet per mile. Erosion of this bedrock resulted in this series of escarpments(55).

Dr. Malott has divided Indiana into 13 physiographic regional units which are perhaps more useful for studying Indiana separately. Using this subdivision the escarpment forms the boundary between the Scottsburg Lowland to the east and the Norman Upland to the west. The Scottsburg Lowland can be described as a broad, shallow concavity and the stream valleys on it are broad and of flat gradient. Silver Creek on the west side of the lowland is typical of these stream types. The Norman Upland is an area described as everywhere being maturely dissected by stream action resulting in long sharp ridges and deep stream trenches. Little Indian Creek

at Floyds Knobs is an example of a stream in a deep trench. Most streams in the area have their valleys essentially perpendicular to the alignment of Interstate Route 64.

The Knobstone escarpment as seen from the east side appears as a solid wall on front rising some 500 feet higher than the Scottsburg Lowland. Upon closer examination it shows some dissection by streams. There are prominent spurs and outliers in the shape of conical hills from which the name, "The Knobs," has been taken. Figure 14 shows the physiographic subdivisions of Indiana.

Topography

The Scottsburg Lowland in the area of New Albany has a general elevation of from 450 to 500 feet above sea level. This area is quite flat with only a minor stream (Falling Run) crossing in the immediate area next to the escarpment.

The Knobstone escarpment presents quite a steep rise from the lowlands. The general elevation of the top of the escarpment just northwest of New Albany is around 920 feet above sea level. This rise is achieved in from one-half to three-fourths of a mile. The face of the escarpment is quite rugged. The Norman Upland has considerable local relief with elevations varying from around 750 feet above sea level in the stream valleys to 900 feet on the ridges. The flat areas are cultivated on the upland but there are steep valley sides which are wooded. The streams in the area are not very large and would not control the location of a road too much except

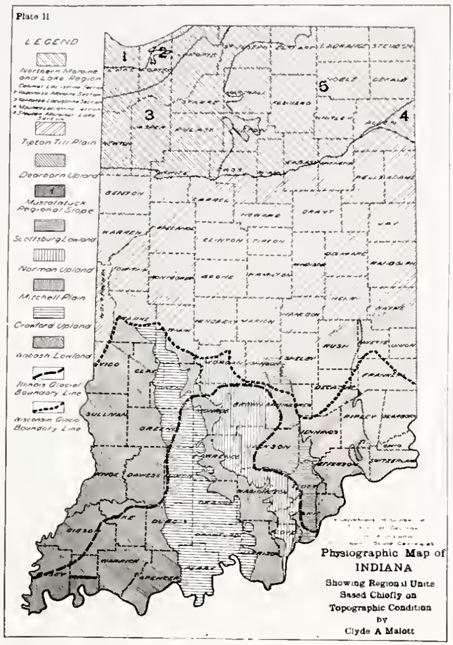


FIG. 14

PHYSIOGRAPHIC PROVINCES OF INDIANA
From Indiana Handbook of Geology

that the valleys follow a north-south trend which necessitates numerous stream crossings on the east-west alignment of Interstate Route #64.

Bedrock and Surficial Geology

The Scottsburg Lowland is a glaciated plain which is broken by broad stream valleys. The surface age represented in the county is the Quaternary period with materials of both glacial and recent origin. The glacial drift is of Illinoian age and is rather thin. The western boundary of the Scottsburg Lowland corresponds to the Illinoian glacial drift boundary and is very irregular along the serrated face of the Knobstone escarpment. New Albany is situated on a granular terrace along the Ohio River. The bedrock underlying the transported surface materials of the lowland is Devonian in age and largely consists of the New Albany shale overlying limestone.

The Knobstone escarpment is relatively free of transported surface materials. The Borden Series of Mississippian age is the rock exposed on the east face of the escarpment as shown in Figure 15. Clays and shales predominate at the bottom of the Borden Series with massive impure sandstone prevailing at the middle and top of the series. The fact that the shale is the more easily eroded material and that it is in the lower position of the series contributes somewhat to the steepness of the escarpment face. Another contributing

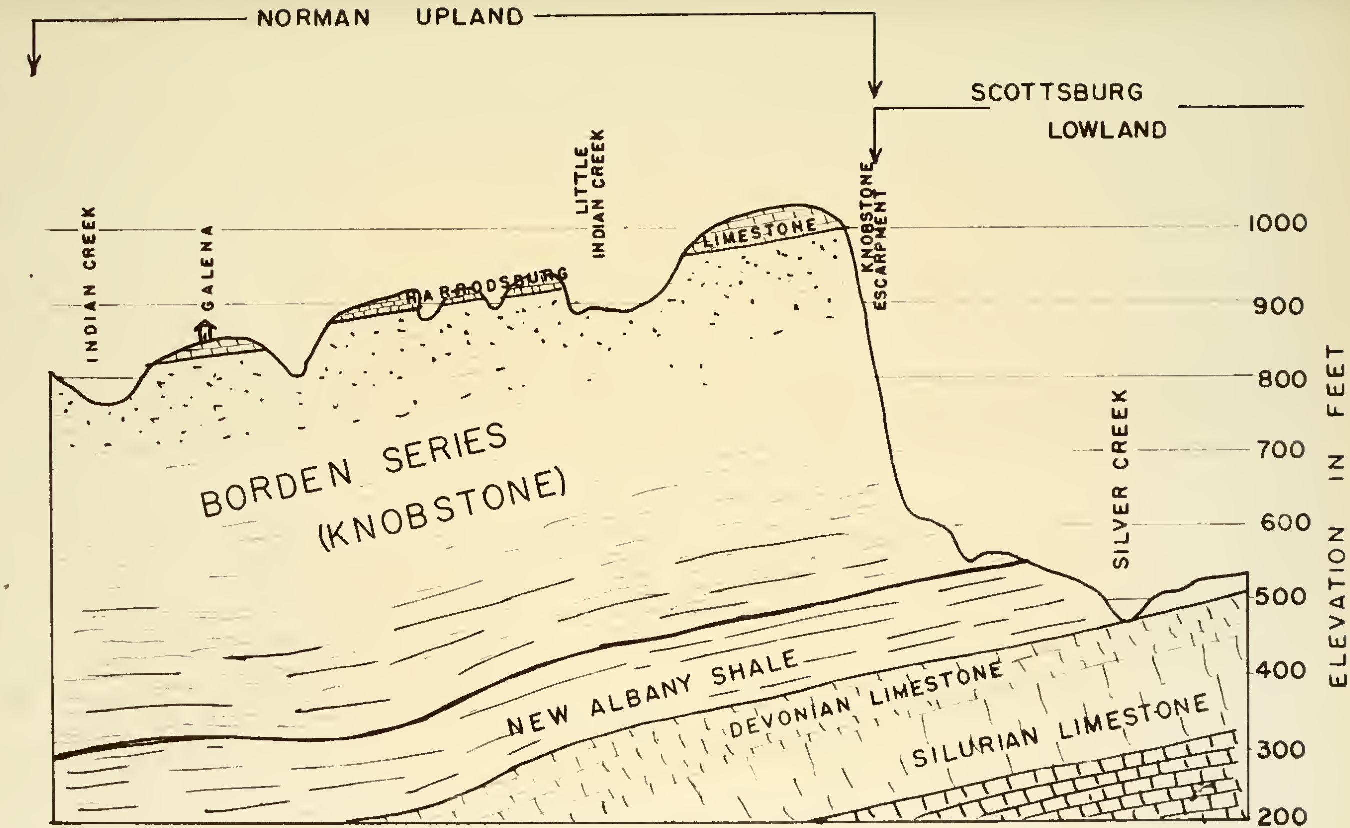


FIG. 15
GEOLOGIC PROFILE
OF
— KNOBSTONE ESCARPMENT —
ABOUT 5 MILES NORTH OF NEW ALBANY

factor to the steepness of the escarpment is the resistant Harrodsburg limestone which acts as a cap rock on the escarpment.

The Norman upland is a limestone plain which has been extensively stream dissected. There are some sinkholes in the western part of the upland where the limestone formations are carbonate and less resistant. The streams in many cases are eroded into the sandstone which underlies the limestone. The bedrock is of Mississippian age. The limestone is very resistant and acts as a cap rock over the sandstones and shales of the Borden Series. Figures 15, 16, and 17 show the geology of the state and the Knobstone escarpment area.

Drainage Features

The study area is drained by the Minor Ohio drainage basin of the state. The Knobstone escarpment acts as a drainage divide with streams to the east flowing generally to the southeast into the Ohio and streams to the west flowing generally southwest into the Ohio as shown in Figure 18.

The streams on the Scottsburg Lowland are flowing in soft shale and are very little controlled by the rock. These streams have broad valleys and flat gradients generally. The streams on the east face of the Knobstone escarpment have steep gradients and V-shaped gullies and are eroding headward faster than those located on the top of the Norman Upland.

The streams on the Norman Upland have, by means of normal stream erosion, eroded the upland to a state of mature dissection in which the volume eroded away approximately equals the

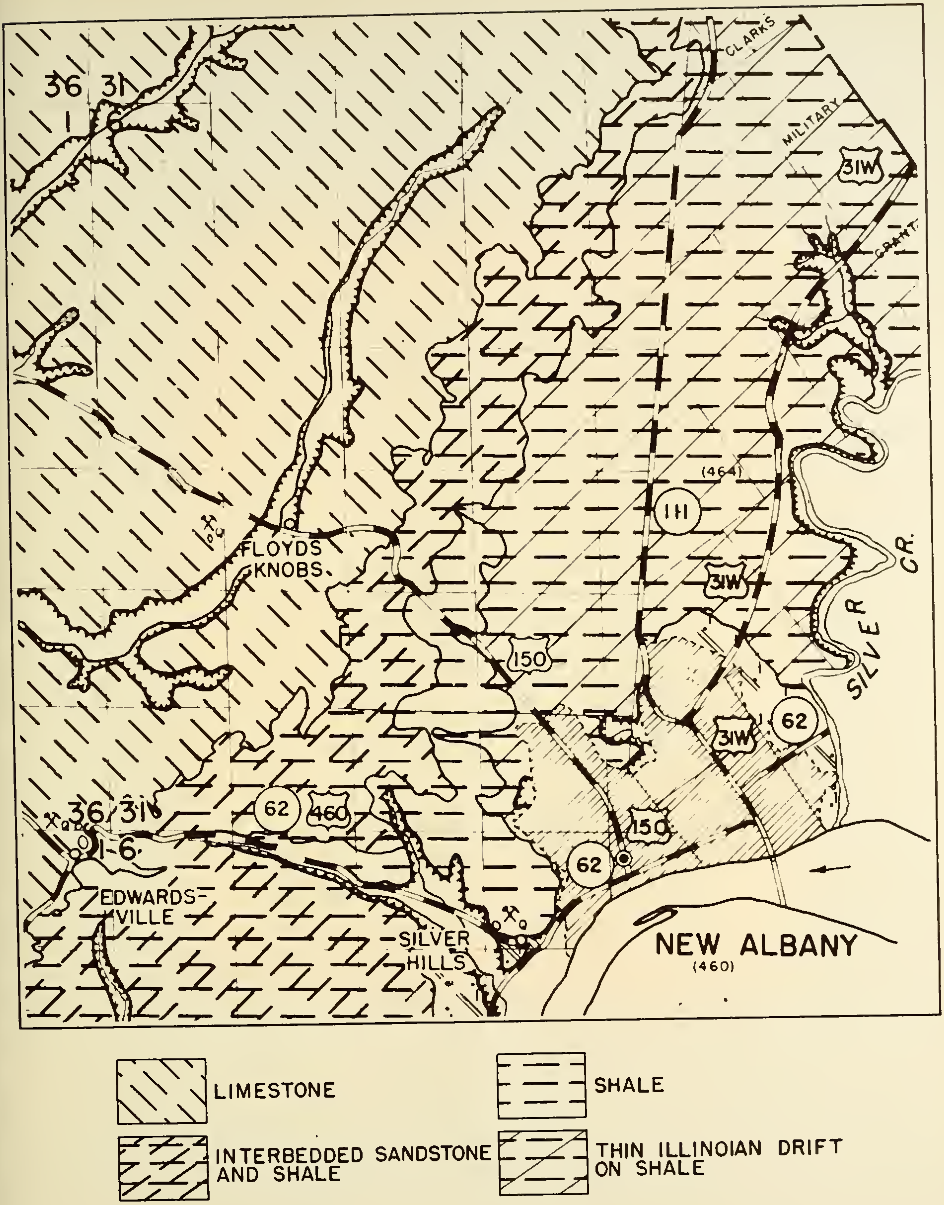


FIG. 16 SURFACE GEOLOGY
NEW ALBANY AREA—FLOYD COUNTY

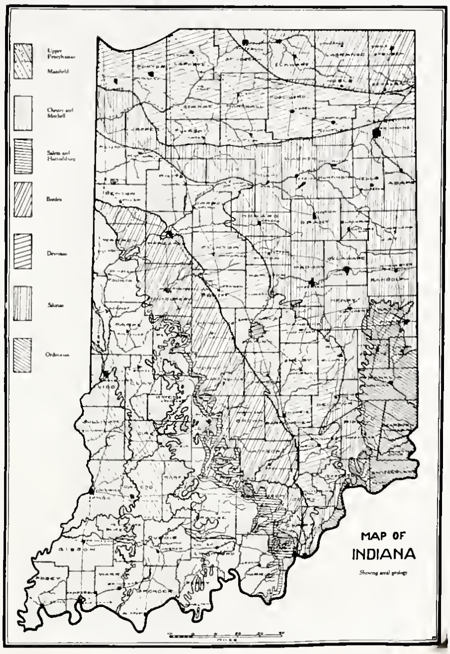


FIG. 17

AREAL GEOLOGY OF INDIANA
From Indiana Handbook of Geology

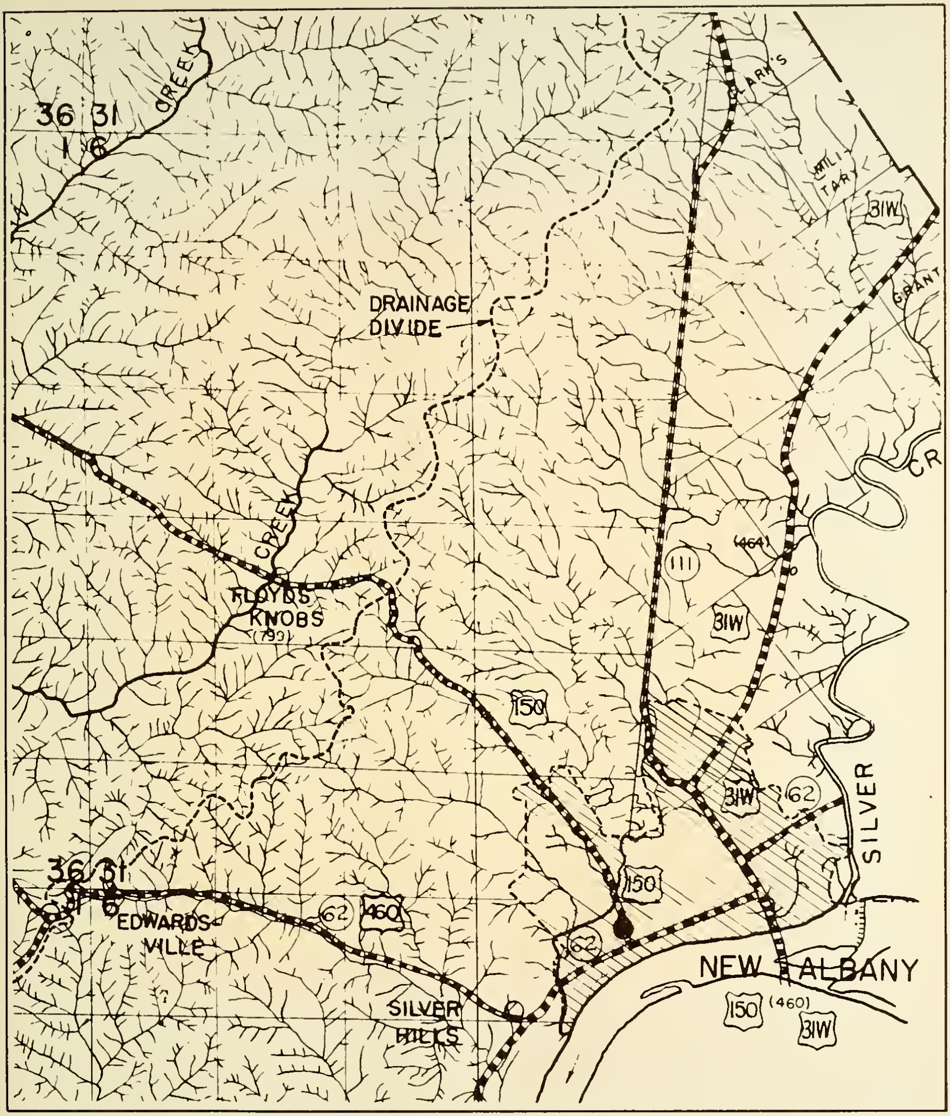


FIG. 18

DRAINAGE FEATURES
NEW ALBANY AREA—FLOYD COUNTY

volume of material left in the ridges.

The area has an average annual rainfall of 40-45 inches. It can be said that the Norman Upland composed of limestone and sandstone is moderately permeable but the Scottsburg Lowland with shale bedrock and shallow soil is slowly permeable. Figure 19 shows the relation to the drainage basins of Indiana and Figure 18 shows the local drainage of the Knobstone escarpment.

Reconnaissance Selection of Possible Routes

Even limiting the reconnaissance study to the 12,000 foot width of terrain photographed for preliminary design mapping the reconnaissance of this area reveals many possibilities for the routing of a highway. They all however must use deep cuts or tunnels in order to cross the escarpment.

Nine such possible routes are marked on the topographic map shown in Plate 2. They all have the same terminal area in the valley of Falling Run.

Route #1 which was considered suitable for a tunnel route is the first one south of Floyds Knobs. It makes use of the narrowest width of the escarpment between Little Indian Creek and a tributary of Falling Run for a tunnel. It then proceeds into New Albany on an easterly course along the tributary of Falling Run.

Route #2, which was considered a possible deep cut route, would pass through the escarpment in a deep cut at the place

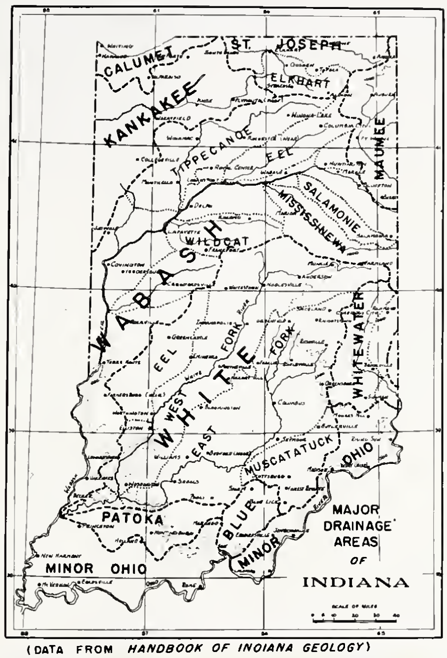


FIG. 19

DRAINAGE BASINS OF INDIANA
From Indiana Handbook of Geology

RECONNAISSANCE STUDY OF ALTERNATE ROUTES

PLATE 2

Old Hill Road makes two right angle turns. It then goes toward New Albany following closely to Daisy Lane.

Route #3, which follows Old Vincennes Road while on the west of the escarpment, would require several deep cuts to cross some spurs of the escarpment in order to descend to the valley below. Once down to the valley floor it would parallel Captain Frank Road into New Albany.

Route #4 would start near Old Vincennes Road and cross the escarpment with a deep cut about in the middle of section 29 and continue straight east through the middle of section 28 and section 27 into the valley of Falling Run and into New Albany.

Route #5 is the most northerly of the routes marked and would start just west of Floyds Knobs and by using a cut in a narrow portion of the escarpment west of Lost Knob it could descend into the valley of Falling Run along the north side of the spur ridge upon which Lost Knob is situated.

Route #6 would use a deep cut to cross the escarpment just north of highway US #150. This route would run parallel and just north of highway US #150 all the way from Floyds Knobs into the valley of Falling Run.

Route #7 would pass just to the north of Floyds Knobs and cross highway US #150 just east of Floyds Knobs and descend by means of a cut through a low saddle in the escarpment which is here 25 to 35 feet lower than any other low spot of the escarpment. Here it would descend about half-way

to the lower valley level and then cross under highway US #150 and then run straight into New Albany along the north side of highway US #150.

Routes #8 and #9 would use the same upper portion and low divide crossing, that Route #7 used, but then would follow on either side of a valley tributary of Falling Run. They would cross highway US #150 on parallel routes just above and below Daisy Lane into the valley of Falling Run and New Albany. These two routes could possibly be used for divided lanes of one highway. They could have lanes at differing grades and would be separated by private property rather than a median of normal width.

Approximate profiles or calculations of lengths and depths of cut and consideration of property values at Floyds Knobs suggested that Routes #1, #2, and #3 presented perhaps the most practical and economic routes for preliminary design studies.

CHAPTER V

SURVEY OF NECESSARY FIELD CONTROL

Introduction

There are three general types of control needed for photogrammetric plotting and mapping; picture points of known vertical elevation, horizontal distances between picture points and picture points of geographic coordinate stations. Most of the United States has been covered by a network of triangulation, traverse and level nets. This information is made available to the surveyor in published form by the U. S. Geological Survey such as is shown in Figures 20 and 21. It is also possible to obtain reliable level and traverse notes from agencies such as county surveyors offices and state highway departments.

Horizontal Control

During the orientation procedure of a real model for mapping it was mentioned in Chapter III that a distance between two identifiable picture points was necessary in order to set a model to scale. It is very necessary that a second distance be taken to have a check on the first's accuracy. These distances should be measured on flat stretches of country and on as long a line as possible to increase their accuracy. It is also desirable to have these two lines at right angles to each other and if possible parallel to the

NEW ALBANY QUADRANGLE INDIANA

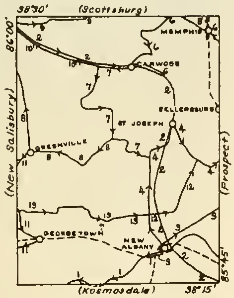
UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Third-order leveling
Sea Level Datum of 1929

N3815-W8545/15
Clark, Floyd, Harrison, and
Washington Counties

11/21/44 feb
12/18/44 WB



1. FROM PROSPECT QUADRANGLE NEAR JEFFERSON WEST ALONG RAILROAD TO ALBANY, THENCE SOUTHWEST ALONG ROADS INTO KOSMOSDALE QUADRANGLE ABOUT 2.0 MILES NORTHEAST OF LANESVILLE (by E. C. Bibbee, 1910; Book A8666, also Bulletin 565)

	Feet
New Albany, on N. end of Monon Route and Pennsylvania R.R. passenger sta. platform; chiseled square	458.67
New Albany, at SW. corner of Main and Vincennes Streets, opposite Monon Route and Pennsylvania R.R. passenger sta.; standard iron post with bronze cap stamped "464" (recovered by first-order leveling, 1911)	463.296

2

	Feet
New Albany, on approach to State Street Pennsylvania R.R. sta.; chiseled square on N. end of second step from bottom	438.70
New Albany, 3.25 mi. W. of, on SW. side of rd. at Y-rd.; standard iron post with bronze cap stamped "502"	501.100
New Albany, 3.89 mi. W. of, on NW. corner of abutment of small iron bridge; chiseled square	481.12
New Albany, 4.2 mi. W. of, on S. side of rd., on limestone ledge; chiseled square	670.17

2. FIRST-ORDER LINE: FROM NEW SALISBURY QUADRANGLE GENERALLY SOUTHEAST AND SOUTH INTO KENTUCKY NEAR NEW ALBANY (by E. L. McNeir, 1911; Book A8834, also Bulletin 565)

	Feet
Borden, 0.6 mi. N. of, 6 ft. W. of track, in E. stone abutment of bridge 298.4; aluminum tablet stamped "577"	576.209
Borden, 3.0 mi. S. of, 120 ft. N. of milepost 302, 10 ft. E. of track, in S. side of stone culvert 301.9; aluminum tablet stamped "520"	519.815
Bridgeport, 400 ft. N. of, 9 ft. W. of track, in S. abutment of steel bridge 303.7; aluminum tablet stamped "504"	503.198
Wilson, 0.9 mi. S. of, 9 ft. W. of track, in top of rock culvert 306.5; aluminum tablet stamped "545" (recovered, 1937)	544.481
St. Joseph, 800 ft. S. of, 10 ft. E. of track, in top of stone arch culvert 309.6; aluminum tablet stamped "547"	546.311
New Albany, 4.8 mi. N. of, 11 ft. W. of track, in stone culvert 312.8; aluminum tablet stamped "536"	534.900
New Albany, 1.0 mi. N. of Monon Route sta., 12 ft. S. of track, in N. side of wye, in E. stone abutment of steel bridge; aluminum tablet stamped "456"	455.245

3. FROM NEW ALBANY NORTHEAST ALONG ROADS 4.8 MILES INTO PROSPECT QUADRANGLE (by C. S. Wells, 1937; Book B7312)

	Feet
New Albany, intersection of State and Spring Streets, in SW. corner of courthouse yard; top of iron pipe stamped "U S E 122" (U.S.C.E. B.M.), painted "B M 452.5"	452.540

NEW ALBANY QUADRANGLE INDIANA N3815-W8545/15 3

	Feet
New Albany, NW. corner of McBeth and 14th Streets, in corner of yard of New Albany Veneering Works, 3.3 ft. from front fence, 2.3 ft. from side fence, 17.3 ft. to corner of house, 17.3 ft. from angle of H.N.; galvanized iron pipe (U.S.C.E. B.M. 936)	446.608
New Albany, 35 ft. NE. of intersection of Spring and Vincennes Streets, on curb at mouth of sewer; chiseled square, painted "B M 462"	462.06
New Albany, 1.5 mi. E. of, on State Highway 62, on E. end of N. rail of concrete bridge over Silver Creek; chiseled square, painted "B M 447.5"	447.52
New Albany, 3.4 mi. E. of intersection of State Highways 231 and 62, in W. angle of triangular intersection, on concrete head wall over culver ; chiseled square, painted "B M 453.1"	453.14
New Albany, 3.8 mi. NE. of, 975 ft. NE. of, McCalloch Chapel School, on State Highway 231, 30 ft. S. and 12 ft. E. from intersection of drive to Heiters chicken hatchery, in concrete post; standard tablet stamped "T T 4 D 1937 453," painted "P B M 453"	453.002
Reference mark, 25 ft. NE. of tablet, on N. corner of concrete head wall over creek; chiseled square	453.63
New Albany, 4.8 mi. NE. of, on State Highway 231, 120 ft. SE. of intersection, on concrete head wall of culvert; chiseled square, painted "B M 471.6"	471.61

4. FROM NEW ALBANY ALONG ROADS GENERALLY NORTH TO ST. JOSEPH, THENCE SOUTHEAST INTO PROSPECT QUADRANGLE ABOUT 2.3 MILES SOUTH OF SELLERSBURG (by C. S. Wells, 1937; Book B7312)

	Feet
New Albany, 1.2 mi. NW. of, on Pearl Street extended, 30 ft. W. of intersection of Bono rd. and Cotton Avenue, 7 ft. E. of maple tree, on concrete curbing; chiseled square, painted "B M 471.1"	471.10
New Albany, 2.0 mi. NW. of, on Pearl Street extended 160 ft. NW. of crossroads, in NW. corner at W. rail base of concrete bridge over creek; chiseled square, painted "B M 462.7"	462.66
New Albany, 2.9 mi. NW. of, 170 ft. S. of forks of rd. E., on NW. wing wall of concrete bridge over stream; standard tablet stamped "6 W 1937 488," painted "P B M 488.2"	487.585

4

	Feet
Reference mark, 40 ft. E. of tablet on N. end of concrete rail base of bridge over stream; chiseled square	488.19
New Albany, 4.5 mi. NW. of, at stream crossing, on S. end of W. rail base of concrete bridge; chiseled square, painted "B M 571.4"	571.32
New Albany, 6.0 mi. NW. of, on Green Valley rd., 2.0 mi. NE. of St. Mary, 110 ft. S. of rd. forks, on W. side of rd., in concrete head wall over drain; standard tablet stamped "7 W 1937 967," painted "967.6 P B M"	967.473
Reference mark, 150 ft. N. of tablet, 40 ft. NE. of rd. forks, in root of persimmon tree; copper nail and washer	971.09
New Albany, about 6.0 mi. N. of, 1.9 mi. W. of Sixmile Switch, 20 ft. SE. of rd. forks, on S. side of rd., on concrete head wall over drain; chiseled square, painted "989.3 B M"	979.24
New Albany, 6.0 mi. N. of, 2.0 mi. S. of St. Joseph, 0.3 mi. W. of Sixmile Switch on Chicago, Indianapolis & Louisville Ry., on foot path up timbered spur to top of knobs, in concrete post; G.S.C. & G.S. standard disk stamped "SIX MILE 1935"	934.145
New Albany, 6.0 mi. N. of, on State Highway 33, 3.0 mi. S. of St. Joseph, 25 ft. NW. of T-rd. W., on concrete head wall over drain; chiseled square, painted "579.6 B M"	579.56
St. Joseph, 300 ft. S. of, on E. side of R.R. track, 500 ft. N. of aluminum tablet stamped "547," on concrete head wall over drain; chiseled square	548.37
New Albany, 4.6 mi. N. of city limit, 2.3 mi. S. of Sellersburg, on E. side of U.S. Highway 31 W., 50 ft. S. and 25 ft. E. from crossing of hwy. and county line rd., on right-of-way near fence line, in concrete post; standard tablet stamped "T T 6 D 1937 499," painted "P B M 498.6"	498.532
Reference mark, 80 ft. N. of tablet, 35 ft. NE. of crossroads in base of telephone pole; rail spike	501.79
New Albany, 5.0 mi. N. of, 3.0 mi. SW. of Sellersburg, on county line rd., 125 ft. SE. of T-rd. SW., 90 ft. NW. of T-rd. SW., on W. side of rd., in root of 30-in. sycamore tree; copper nail and washer, painted "B M 474.7"	474.69

FIG. 20

NEW ALBANY QUADRANGLE INDIANA

UNITED STATES DEPARTMENT OF THE INTERIOR

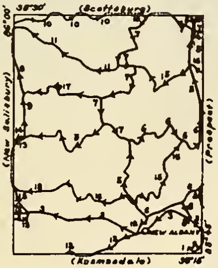
GEOLOGICAL SURVEY

TRANSIT TRAVERSE
North American Datum of 1927

N3815-W8545/15
Clark, Floyd, Harrison, and Washington Counties

Magnetic declination for the quadrangle is: 1°19'E.

bb 5/17/44



STATION	DISTANCE Feet	LATITUDE ° ' "	LONGITUDE ° ' "
LINE 1. J.R. Ellis, 1904; Book 3580			
Louisville, Ohio River Survey, U.S. Army Engineers station 602M+285, 1903	....	38 15 32.71	85 45 54.68
LINE 2. C.B. Kendall, 1905; Book A40			
Louisville Catholic Cathedral at Fifth and Walnut Streets, center of spire	....	38 15 06.711	85 45 31.960
[Jogs into Prospect quadrangle]			

STATION	DISTANCE Feet	LATITUDE ° ' "	LONGITUDE ° ' "
Jeffersonville, 2.2 mi. N. of, center of rd. and track at crossing	(7782)	38 18 14.30	85 45 05.18
Pennsylvania and Baltimore & Ohio R.R. crossing, 500 ft. N. of, center of track at rd. crossing	5849	38 19 12.05	85 45 04.64
[Jogs into Prospect quadrangle]			
Sellersburg, 150 ft. N. of sta., center of track and street, at crossing	(8900)	38 23 41.64	85 45 01.04
222.=Sellersburg, at S. end of sta.; standard iron post with bronze cap stamped "Prim Trav Sta No 1 1905"	164	38 23 43.28	85 45 01.68
Speeds, 250 ft. S. of sta., center of rd. and track at crossing	6060	38 24 41.33	85 45 08.85
Speeds, 1 mi. N. of sta., center of track and second-class rd. at crossing	5668	38 25 36.90	85 45 17.97
Rd. crossing and E.-W. township line, 500 ft. S. of milepost L 14, center of track	6383	38 26 35.76	85 45 46.91
Rd. crossing, 800 ft. N. of milepost L 15, center of track	6581	38 27 39.32	85 46 00.68
Rd. crossing, 400 ft. S. of milepost L 16, center of track	4037	38 28 19.32	85 45 52.60
Memphis, 475 ft. N. of sta. at crossing of Main Street, center of track	4369	38 29 01.73	85 45 42.21
LINE 3. C.B. Kendall, 1905; Book A40			
Jeffersonville, Beckett Street crossing, center of tracks	(3026)	38 16 39.71	85 45 27.26
New Albany, 1.1 mi. E. of B. & O. S.W. R.R. sta., N. rail of S. track at crossing	13101	38 17 42.81	85 47 06.38
New Albany, near B. & O. S.W. R.R. sta., center of N.W. intersection of Main and Vincennes Streets	5887	38 17 22.99	85 48 15.99

NEW ALBANY QUADRANGLE INDIANA N3815-W8545/15 3

STATION	DISTANCE Feet	LATITUDE ° ' "	LONGITUDE ° ' "
New Albany, State Street and Pennsylvania Interurban R.R. crossing, center of N. main track	5777	38 16 58.19	85 49 21.23
New Albany, Budd rd. crossing at E. edge of town, center of track	5712	38 16 25.10	85 50 19.26
New Albany, 2 mi. W. of Southern Ry. sta., center of rd. and track at crossing	4884	38 16 40.18	85 51 17.43
Duncan Hill tunnel, 1.6 mi. SE. of, center of pike and track at crossing	6489	38 17 05.86	85 52 32.01
Duncan Hill tunnel, 0.4 mi. SE. of, center of pike and track at crossing	6050	38 17 12.77	85 53 47.40
Duncan, 0.25 mi. SW. of sta. at post office in store of J.S. Nichols, at SE. corner of store and N. edge of Edwardsville-Georgetown pike, 300 ft. S. of center of main track of Southern Ry.; standard iron post with bronze cap stamped "Prim Trav Sta No 4 1905"	8001	38 17 14.22	85 55 27.69
Duncan, 100 ft. E. of post office, 229 ft. S. of track, public land survey corner	510	38 17 14.89	85 55 27.31
Georgetown, 1.6 mi. SE. of sta., center of pike and track at crossing	6425	38 17 45.79	85 56 45.52
Georgetown, 680 ft. E. of sta., center of track at street crossing	7583	38 17 38.36	85 58 20.57
Georgetwon, 1.6 mi. W. of sta., center of rd. and track at crossing	7919	38 17 13.78	85 59 54.85
Georgetown, 1.25 mi. W. of, T-rd. S.	1883	38 17 07.66	85 59 32.53
1163.=Georgetown, 1.25 mi. W. of, 0.2 mi. S. of Southern Ry., on line between secs. 5 and 6, T. 3 S., R. 5 E., in SE. corner of junction; standard iron post with bronze cap stamped "Prim Trav Sta No 5 1905"	34	38 17 06.37	85 59 32.25
T. 3 S., R. 5 E., cor. secs. 5, 6, 7, and 8, at bend of rd. to E., stone	4505	38 16 23.19	85 59 32.61

4

STATION	DISTANCE Feet	LATITUDE ° ' "	LONGITUDE ° ' "
LINE 4. C.A. Turner, 1937; Book D2402			
12+. Fork of rd. N.45°E	(3753)	38 28 50.28	85 45 05.86
15. Silver Creek, center of rd., NE. end of iron bridge	811	38 28 53.33	85 45 15.29
LINE 5. C.A. Turner, 1937; Book D2402			
20. Memphis, 475 ft. N. of sta., center of street and track at Main street crossing	2292	38 29 01.61	85 45 42.11
23. Memphis, on Pennsylvania R.R., 75 ft. E. of center line of U.S. Highway 31, 29 ft. S. of center line of dirt rd., 12 ft. W. of W. rail, at bridge 93-53, in top of third step from bottom of W. end of S. abutment, 9.5 ft. S. of N. end of step, 9 ft. E. of W. edge, 4.5 ft. lower than the track; U.S.C. & G.S. standard disk stamped "A 60 1934"	1500	38 26 46.89	85 45 44.34
27+. On line between grants 203 and 220, center line of Pennsylvania R.R. track, opposite brushy fence line N. 53°E. on N. side of private lane, painted on corner post "489.5"	3361	38 29 20.12	85 45 44.70
28+. Memphis, 0.7 mi. NW. of, public rd. crossing track at painted elevation "489.3"	1777	38 29 37.60	85 45 47.11
29+. Center of track at S. abutment of bridge 92/11	2256	38 29 59.78	85 45 50.18
LINE 6. R.C. Darnell, 1937; Book D2321			
62+. Center of old Charlestown Pike and ~~Pennsylvania~~ R.R.	(3057)	38 19 12.05	85 45 04.64
63+. Intersection of U.S. Highway 31 and State Highway 231	260	38 19 10.57	85 45 07.38
66. New Albany, 3.8 mi. NE. of, 975 ft. NE. of McCulloch Chapel School on State Highway 231, 30 ft. S. and 12 ft. E. from intersection of drive to Meiers chicken hatchery, in N. corner of yard, in concrete post; standard tablet stamped "T T 4 D 1937"	4954	38 18 42.02	85 45 57.87
68+. Intersection of Hollywood Boulevard and State Highway 62 known as Charlestown rd.	4039	38 18 19.33	85 46 39.56
71+. Silver Creek, center of concrete bridge on State Highway 62, on Clark-Floyd county line	4422	38 18 02.54	85 47 50.79

FIG. 21

Department of Commerce
U.S. Coast and Geodetic Survey

GEOGRAPHIC POSITIONS

Rev. 2-26-51 Ind. 27

Accession No. of Computation 83×90

Locality Louisville, Ky. to Nashville, Tenn. Datum North American, 1927 State Kentucky ~ Indiana

Station	Latitude and Longitude (° ′ ″)	Elevation (meters and feet)	Azimuth (° ′ ″)	Back Azimuth (° ′ ″)	To Station	Distance: Logarithm (meters)	Distance: Meters	Distance: Feet
Lutz (Ind) 1884	38 24 34196	183.4	95 32 2684	275 26 58.60	Popp	4 109 7506	12 875.10	42 241 1
1933, r.'35 d.m.	85 40 07 240	601.6	179 14 55.92	359 14 53 16	O. and M.	3.913 8771	8201 19	26 906.7
Six Mile (Ind)	38 22 37843	284.7	178 06 54 30	358 06 50 24	Popp	3683 3319	4823.16	15 824 0
1884, 1914, r.'1933, '35, d.m	85 48 48 966	934	226 44 29 98	46 49 51 51	O. and M	4 235 9294	17215 89	56 482.5
r. 47			254 08 04 40	74 13 28 42	Lutz	4 119 2405	13159.53	43174.2
			347 15 38.9		Azimuth mark (white church, cupola)			
			343 50 209					
Sims (Ind.) 1884	38 20 35877		105 55 08 75	285 49 30 66	Six Mile	4 138 3193	13 750.53	45113.2
r. 1933, r.'35 d.m	85 39 44.197		122 43 09 77	302 37 27 46	Popp	4 201 2937	15896.21	52 152.[illegible]
			175 38 5719	355 38 4288	Lutz	3867 4387	7369 51	24 178.1
			329 40 39 6		Azimuth mark			
Blind Asylum-2 (Ky)	38 15 24149		146 43 5303	326 40 08 84	Six Mile	4 204 0971	15999 16	52 490.6
1933, r.'35 d.m	85 42 47389		204 50 02 92	24 51 56 46	Sims	4 024 9914	10592.33	34 751.7
Bangs (Ind) 1879	38 19 36.617	279.3	212 47 02.18	32 48 34 19	Six Mile	3 822 6572	6647.48	21809 3
r. 1933, r.'35, '47 d m	85 51 17.255	916 √	263 44 41.76	83 51 51.64	Sims	4 228 6891	16 931 25	55 548.6
			302 05 43 27	122 10 59 22	Blind Asylum 2	4 165 3307	14632.91	48 008 1
			354 12 21.0		Azimuth mark			
Cox (Ky.) 1879	38 09 24.155	230.0 √	159 00 45.01	338 57 40 37	Bangs	4 305 9807	20229.29	66 368.9
r. 1933, r.'35 d.m.	85 46 18.966	754 √	204 51 43 77	24 53 54.63	Blind Asylum 2	4 087 6103	12235.18	40141.6
			243 07 55 5		Azimuth mark			

Department of Commerce
U.S. Coast and Geodetic Survey
Form No. 789

PLANE COORDINATES

Revised 6/17/49; 1/5/54 7

State Indiana Locality Toledo to Chicago / Louisville, Ky. to Nashville, Tenn. Datum North American 1927 Projection Transverse Mercator Zone East G 3986

Station	x Coordinate / y Coordinate (Feet)	Azimuth (° ′ ″)	Mark	Station	x Coordinate / y Coordinate (Feet)	Azimuth (° ′ ″)	Mark
				Blind Asylum-2 (Ky)	486 648 22		
				1933 d.m	275 545 99		
Blocher 1914	503 482.36	10 43 05 √	Azimuth mark	Bangs 1879	446 033 10	354 19 21 *	Azimuth Mark ←
r. 1931, r. 1935, r. 1947 d.m	446 454 58			r. 1933 d.m.	301 136.06		
Finley 1914, r. 1931	438 506 45	72 05 06 √	Azimuth mark	Cox (Ky) 1879	469 730 40	243 11 50 *	Azimuth Mark
r. 1935, r. 1946, r. 1947 d.m	413 496 12			r. 1933 d.m	239 145 02		
Summit 1886, r 1914	461 353 35			Williams	429 081.96	31 05 17 *	Azimuth Mark
r 1931, 1935, 1947 d.m	390 037 13			1879, r. 1933 d.m	245 337 92	310 22 04 *	Green barn, ventilator
Marysville 1914	505 378.65			Potts	422 635 01	213 00 05 *	Azimuth Mark
r. 1935 d.m	396 592.77			1880-82, r. 1933 d.m	214 918 00		
O. and M 1884	499 071.56			Riley 2 (Ky.)	486 410 80	293 36 26 *	Azimuth Mark
r. 1915, r. 1935 d.m	358 086 88			1933 d.m.	215 488 44		
Popp, 1914, r 1933,	457 381.49			Mountain Top (Ky.)	466 286 50	230 43 32 *	Azimuth Mark
r. 1935, r. 1947 d.m	335 262.49			1880, r. 1933 d.m	154 080 31		
Lutz 1884	499 423 71			Snow (Ky.)	403 115.98	147 16 27 *	Azimuth Mark
r. 1933 d.m	331 183 24			1933 d.m	144 836 42		
Six Mile,	457 876 78	347 21 07 *	Azimuth Mark	Purcell (Ky.)	449 283.86		
1884, 1914, r 1933 d.m	319 446 82	343 55 40 *	white church, cupola	1933 d.m	89 655 78		
Sims, 1884	501 259 03	329 40 30 *	Azimuth Mark				
r 1933 d.m	307 075 66						

√ No check on this position * This azimuth has been computed by the $\Delta\alpha$ formula neglecting the second term

FIG. 22

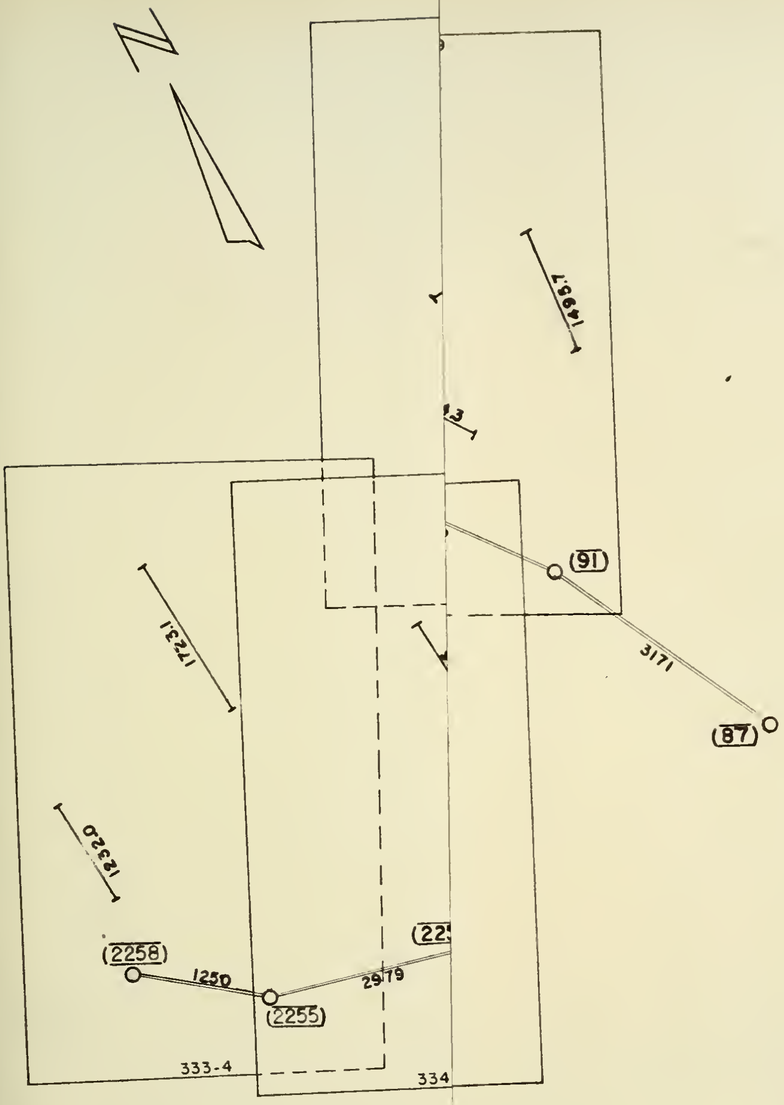
X- and Y-axis of the plotter. The problem of the New Albany escarpment was to find long straight distances which could be identified and which were situated near the photograph's center. A total of 43,180 feet was chained in 34 different lines. This gave an average of 3 lines of 1220 feet per model. Figure 23 shows the positioning of the horizontal control points.

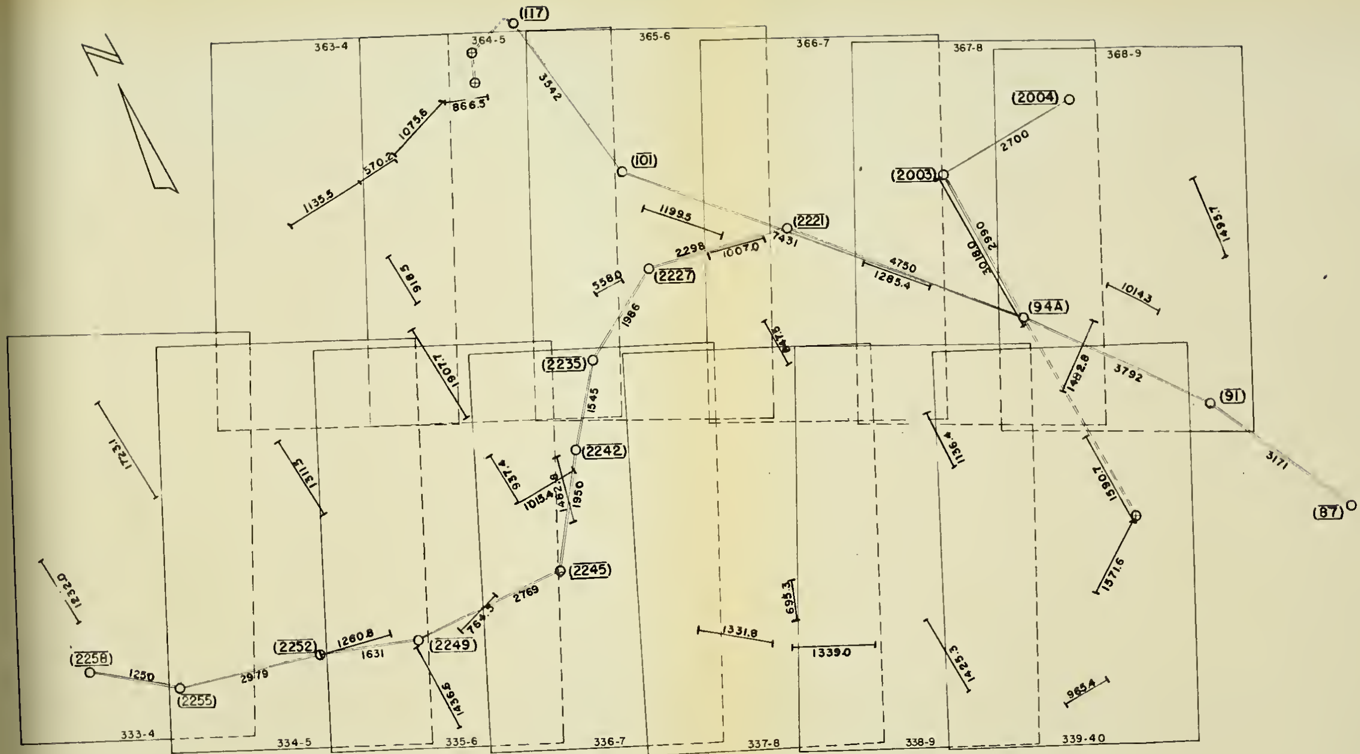
Vertical Control Measurements

In order to be able to read elevations of a model or to plot contours there must be a reference or datum plane. In surveying this datum plane is generally mean sea level. One such known elevation in a three dimensional model is not sufficient as three points in space are needed to define a plane. However, in accordance with good surveying practice a fourth elevation is needed to serve as a check on the first three. Four elevations then are a theoretical minimum, but practically, it is seldom that these four points will fall in the four corners of the model; therefore, it is generally recommended that six points be the bare minimum for plotter orientation.

For the mapping in this thesis work various sources of information were used for vertical control points. The sources of spot elevations were:

(1) U. S. Geological Survey Quadrangle Sheets of the 7½ Minute Series: spot elevations shown for road intersections and given to the nearest foot were available for a total of


N
1495.7
(91)
3171
(87)
1723.1
1232.0
(2258)
1250
(2255)
2979
333-4
334



Chained Distances
Co-ordinate Stations
Geological Survey Transit Traverse
Traverse Extension

STATE PLANE CO-ORDINATE CONTROL POINTS
and
HORIZONTAL PICTURE CONTROL POINTS

FIG. 23

22 points.

(2) Some State Highway Department of Indiana bench marks were found along highway US #150. These were in the form of spikes in poles and trees and it was necessary to take a level reading on some nearby distinguishable picture point. Five points of this type with elevations recorded to tenths of a foot were usable in establishing five picture point elevations.

(3) Some city of New Albany elevations on curbs and at centers of intersection were identified inside the mapping area and were suitable for picture point elevation. There were approximately 20 of these used.

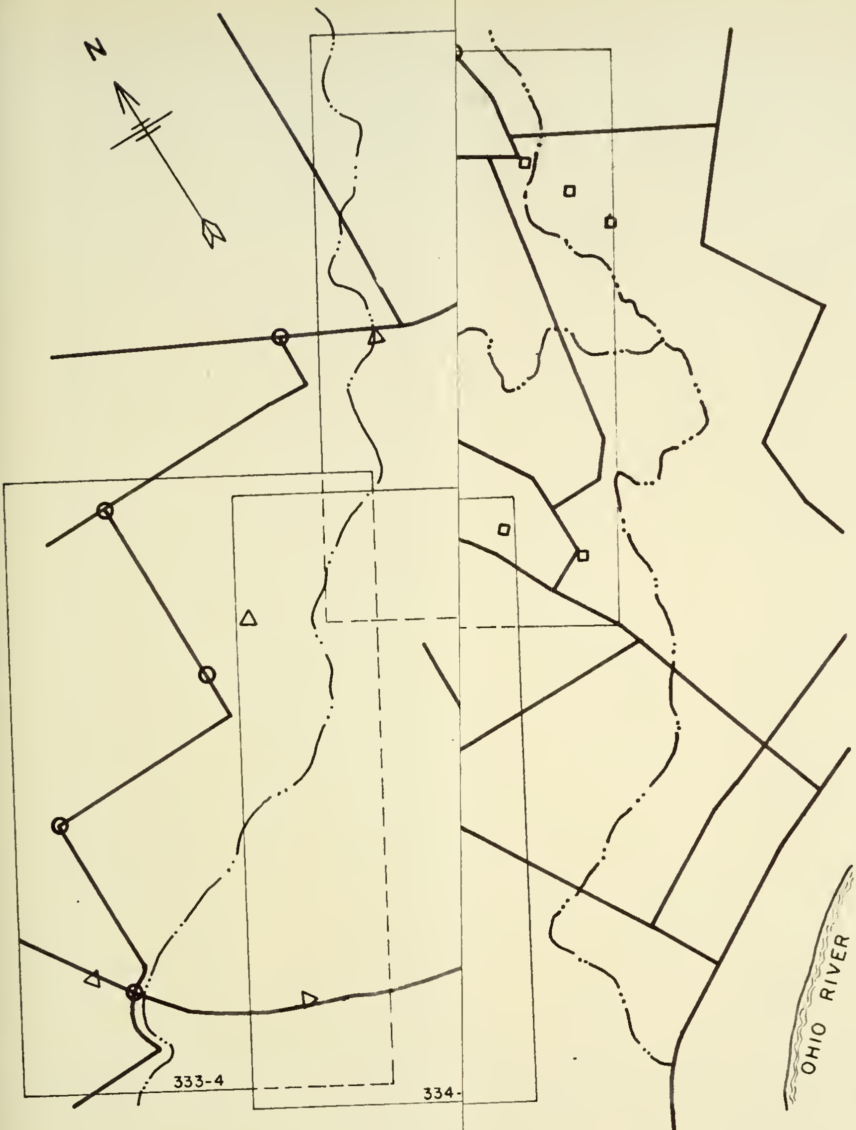
(4) Additional levels were run from the above mentioned data to obtain 45 supplementary elevations of picture control points. In order to obtain these points about 57,000 feet of level circuits were run with a Wye level and rod.

(5) In addition to the above levels obtained by the author, Indiana State Highway Department employees supplied an additional 35 spot elevations.

Figure 24 shows the positioning of the vertical control points with respect to each model.

State Plane Coordinate Control Points

The use of a system of plane coordinates is necessary in order to have overall control of the assembly of the individual stereomodels into a large map. It is also possible to use coordinate distances for horizontal scale settings if two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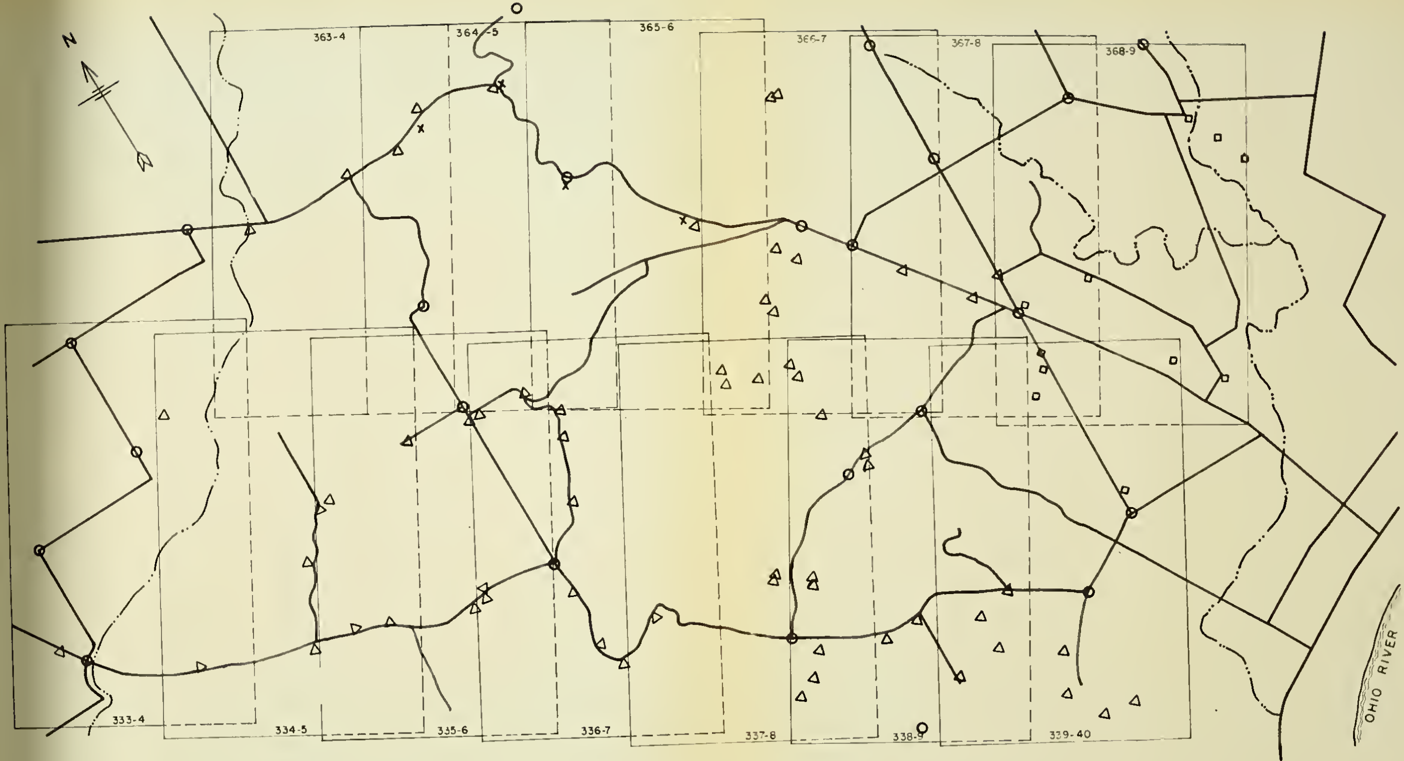
333-4
334-
OHIO RIVER



SOURCES OF ELEVATIONS

USGS TOPOGRAPHIC SHEETS O

CITY BENCH MARKS □

STATE HIGHWAY LEVELS X

FIELD SURVEYS △

VERTICAL PICTURE CONTROL POINTS

FIG. 24

coordinate stations are present in one model.

The state plane coordinate points in this area were quite numerous as the Geological Survey had two transit traverses passing thru most of the area being mapped. There was a total of 13 traverse stations located on 8 of the 13 models. Two other coordinate points were extablished on 2 photo models. This left 3 models to be assembled into the whole map by using picture pass points of the adjacent models. The 13 coordinate stations needed very little field work for identification as most of them were at the center of road intersections or some other recognizable point. Three coordinate monuments required field checking for positive identification.

The position of the state coordinates is shown in Figure 23. The coordinates are given in geographic terms and must be converted to plane coordinates. The sources of traverse and triangulation coordinates are shown in Figure 22. A description of state plane coordinate systems and a sample calculation of a state plane coordinate are shown in Appendix A.

Because state plane coordinates are not too well known, a description of some of the advantages in their use may be helpful.

1. It is possible to check the accuracy of a plane survey by starting from a coordinate position and closing on another coordinate position and thus eliminating a long return ground survey closure.

2. It is possible for surveyors to restore old monuments or establish new ones by measurements from existing monuments with the aid of coordinate positions shown only on maps.

3. It is possible to start work on segments of a highway project which was planned on maps having coordinate positions before a complete continuous ground survey has been made with assurance that the whole survey will have the continuity planned originally.

4. The practice of assigning coordinate values to a state which are always positive simplifies calculations and eliminates some of the chances of error.

5. The use of coordinates and geodetic markers eliminates the possibilities of errors of an older survey being carried over into a new survey.

6. The coordinate system permits obsolete land descriptions and land with lost markers to be brought up to date and redescribed.

7. In urban areas where land values are high and accuracy requirements are high the use of coordinates are particularly valuable in locating points before the right-of-way is cleared; thus, eliminating preliminary surveys.

Accuracy Check Survey

Most agencies employing photogrammetric means of surveying will conduct an accuracy check in the form of a comparison of vertical elevations and positions as surveyed in the field in conventional manner with plotted contours and coordinate positions on the photogrammetric map.

For this thesis project the Indiana State Highway Department was asked to run a check profile. In order to obtain a fairly long line without too much interference with trees and farms, Old Hill Road was selected as the site. A straight line 7000 feet long was surveyed with a transit and tape and then a level circuit was run along this center line securing elevations every 20 feet. These notes were then turned over to the author to be used as a check on the photogrammetric plotting.

CHAPTER VI

PHOTOGRAMMETRIC PLOTTING AND MAPPING PROCESS

Introduction

The author, not having any previous experience with photogrammetric equipment, had to learn to operate the Kelsh plotter largely by practice on some mapping for the Indiana State Highway Department and on this thesis project. The equipment available was a Revised GS 1953 Kelsh Plotter (48) equipped with 8¼-inch focal length projectors and a Bausch and Lomb English Type tracing table. The plotter is set up in a room 14 feet by 14 feet that can be darkened completely and also is equipped with an air conditioner to keep misture changes of paper to a minimum. The drawing boards available were Kromo-Lite dimensionally stable card-board.

Plotting Methods

The Kelsh plotter was equipped with 8¼-inch focal length projectors giving an enlargement of four diameters. Aerial photography with 8¼-inch focal length camera provided contact prints and diapositives at a scale of 800 feet-per-inch; therefore, it was possible to plot at 200 feet-per-inch.

The determination of the contour interval to use was the most difficult decision. The prints were of good quality and were taken at a 6600 foot altitude. A Kelsh plotter C-factor of 1000 would indicate that a 6.6-foot, or almost a 5-foot

FIG. 25

MAPPING WITH A KELSH PLOTTER

contour interval was theoretically possible, if good vertical control was available. However, there were several items which suggested a 10 foot interval be used instead. The first limiting factor was the time element required to do the field surveys.

Because time was limited and accurate bench marks were not within the working area it was decided to use whatever available elevation data was present and to supplement this with additional elevations where they were absolutely needed. Use was made of city elevations, highway plan elevations, and spot elevations shown at intersections on recent quadrangle sheets. It was not possible to tie all of these elevations together and to check their accuracy and so they were assumed to have an accuracy of plus or minus one foot. Other factors favoring the use of a 10-foot contour interval were: the extreme rugged topography in certain areas which made it difficult locating picture points for control purposes in ideal locations; the extensive tree cover in some areas; and a too dense coverage of contour lines in some areas would have left little space for other topographic detail.

The order of plotting was not rigid, but the practice generally followed was to plot the structural features first: such as, houses, fences, and roads. Secondly the contours were traced on a quarter or half a sheet at a time. Contours were started at the lowest points and carried up to the highest point so that no area would be overlooked. The contours

were indexed as drawn and then retraced to smooth out any unnatural unevenness in their shape. After the contours were drawn tree lines were traced and checks made to see that nothing was omitted. The symbols used in mapping were similar to those used on quadrangle sheets or in use by the Indiana State Highway Department.

Manuscript Assembly

There were 13 models plotted, 7 in one flight line and 6 in the other which had to be assembled into a working drawing. The best means of assembly was to trace the models onto two rolls of tracing lines. A 1000 foot grid based on the state plane coordinate grid was ruled on the linen and as there were some points on most models with a coordinate designation, these stations were marked on the tracing boards and positioned under the linen and traced completely onto the linen as shown in Figure 26 . The models were traced first which had the most number of coordinate points and the ones with fewer points next and those lacking any points were traced last and fitted into the rest of the tracing by picture point identification. The finished linens were marked with coordinate grid numbers and any other names that were necessary. These linens were then used to make ozalid prints to work on and study. The 13 models plotted are shown in Figure 27.

The use of the coordinates considerably aided the assembly of the adjacent models in the flight lines and aided in controlling the tieing of the two flight lines together as well

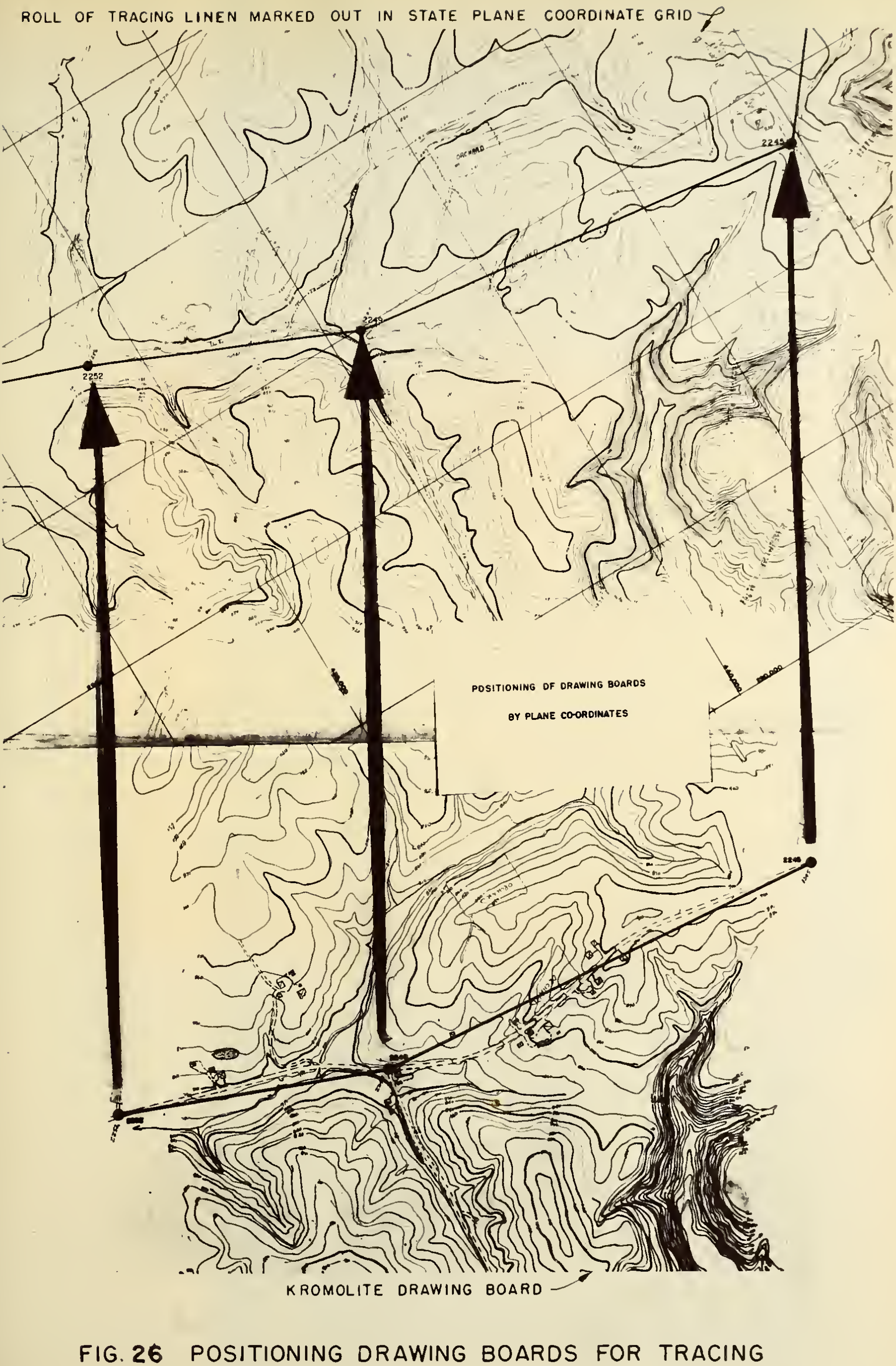
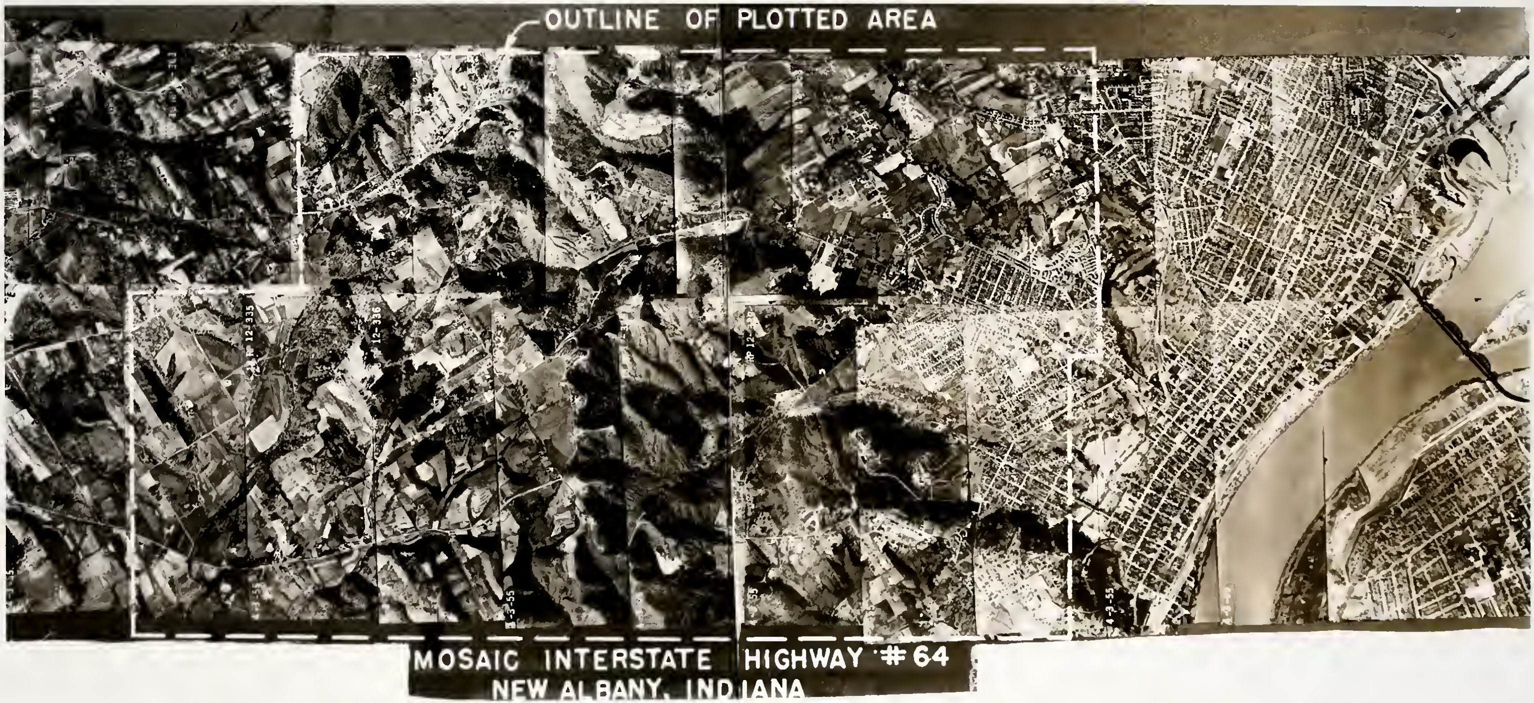


FIG. 26 POSITIONING DRAWING BOARDS FOR TRACING


OUTLINE OF PLOTTED AREA
MOSAIC INTERSTATE HIGHWAY #64
NEW ALBANY, INDIANA

as the establishment of the state plane coordinate grid. There were 15 transit traverse positions of the Geological Survey located in the area being mapped which were fairly well situated, and which along with two supplementary points surveyed from traverse stations, gave a network of 17 control points used to position the models correctly with respect to the state plane coordinate grid. A listing and description of the state plane coordinate stations used is shown in Table 19 in Appendix A.

Accuracy Check of the Photogrammetric Map

Vertical Accuracy

National standards of map accuracy were used as the criteria for vertical accuracy. The National Standards of Map Accuracy "as applied to contour maps at all publication scales, shall be such that not more than ten percent of all elevations tested shall be in error more than one-half of the contour interval" (23).

A 7000 foot transit and level test line was obtained in the field with 20 foot stations. This 7000 foot profile was then plotted on profile paper.

From the plotting boards the distances were scaled from the origin of the check profile to the point where each contour crossed the center line; also distances were scaled to some ridge and valley lines and the elevations of these intermediate points were estimated from contour interpolation.

Approximately 45 points of known elevation were recorded in this manner and then plotted as spot elevations on the same profile sheet as the check line profile. A second and third profile line one half a contour interval away, one below and one above the ground profile were drawn on the profile sheet to see if the points tested fell within the half contour band. An analysis of the 45 points (see Plate 3) tested shows that:

18 points were in error from 0 to 1 foot.

8 points were in error from 1 to 2 feet.

10 points were in error from 2 to 3 feet.

6 points were in error from 3 to 4 feet.

3 points were in error from 4 to 5 feet.

0 points were in error from 5 or more feet.

Horizontal Accuracy

The horizontal accuracy of mapping is usually defined as the allowable difference between the plotted position of a well defined point and its true map position at the plotted map scale.

The National Standards of Map accuracy specify that 90 percent of all points tested shall not be in error more than 1/30-inch on maps published at scales larger than 1/20000. Engineering map specifications usually specify 90 percent of all planimetric features shall be within 1/40-inch of their true coordinate position and none shall be in error more than 1/20-inch from their true position (23). For maps at 200 feet-per-inch as used in this project the error tolerances

for horizontal measurements are:

National Standards of 1/30-inch = 6.6 feet for 90 percent of points tested.

Engineering Map Standards maximum of 1/20-inch = 10 feet.

Engineering Map Standards 1/40-inch = 5 feet.

It was possible in this project to test the horizontal accuracy in two ways; by using the topography references along the 7000 foot check profile run by the State Highway Department and by the use of U. S. Geological Survey Transit traverse notes.

The profile notes gave distances along the center line of Old Hill Road from its junction with Old Vincennes Road to objects such as building corners, power poles, and fence corners. It was possible to check the distances along this center line to objects up to about 3000 feet from the origin. It was not possible to check the remainder of the line as the center line cut across the corners of 3 plotting boards and the tie to the origin was thus lost. For the 3000 feet tested all the objects plotted were checked with the chained distances. The following list of twelve points gives a comparison between map and taped distances:

Table 1

Horizontal Accuracy Test 1

Object	Distance (feet) Measured	Distance (feet) Mapped	Error (feet)
Telephone pole, east side of the road	161	157	-4
Telephone pole, east side of road	424	420	-4
Fence corner post, west side of road	428	425	-3
Power pole, west side of road	564	558	-6
Fence corner post, west side of road	639	632	-7
Telephone pole, east side of road	647	640	-7
Barn corner, west side of road	759	750	-1
Fence corner post, east side of road	1411	1403	-8
Telephone pole, east side of road	2200	2200	0
Power pole, west side of road	2339	2340	+1
Telephone pole, east side of road	2588	2585	-3
Fence corner post, east side of road	2588	2585	-3
Fence corner post, east side of road	2875	2878	+3

The U. S. Geological Survey traverse shown in Figure 23 which traversed the area, when plotted had 9 sides of the traverse which were completely on a single plotting board and therefore could be used to check horizontal distances. It was not possible to obtain well defined points for any of these traverse stations as they were described in such terms as "center of road intersection" and the interpreted map positions

of these stations could very well be in error by several feet. The errors shown then in the following summary do not depend on one plotted position but are the result of two plotted positions. Even though these stations were not well defined it was felt that the lines served as useful checks because of the long distances of the traverse sides relative to the size of the model. The comparison of the plotted traverse lengths compared to the true lengths are as follows:

Table 2

Horizontal Accuracy Test 2

U. S. Geological Survey Traverse Sides Station to Station		Distance (feet) U. S. G. S. Traverse	From Plotted Map	Error (feet)
2004	2008	2158	2150	- 8
91	94	2792	3780	-12
94	2003	2990	2985	- 5
2003	2004	2700	2690	-10
2245	2249	2769	2775	+ 6
2249	2252	1631	1625	- 6
2242	2245	1950	1940	-10
2227	2235	1986	1990	+ 4

CHAPTER VII
THE PRELIMINARY DESIGN OF
THREE ALTERNATE ROUTES

Introduction

Of the many possible routes explored in the reconnaissance stage three routes were considered good enough for further studies. As this was to be a preliminary design stage it was decided to select alignments from the topographic map sheet using Interstate standards of alignment and then to draw profiles and select approximate grade lines. From this center line profile it was then possible to estimate cut and fill volumes on the basis of average cut or fill on the center line for a 100 foot station.

Selection of Design Standards

The section of road studied for this project lies along the general route of one of the proposed Interstate highways. The design standards for the highway will have to be at least up to Interstate standards and up to Indiana Highway Department standards whenever they are higher. The Interstate standards adopted on July 12, 1956 (1) are to apply to all new Interstate highways and are intended to be minimum values where there may be excessive costs in going to higher standards. The American Association of State Highway Officials (AASHO) design guides for rural, urban, and bridges are

to be used as guides providing they do not conflict with the Interstate standards.

Traffic as the Basis for Design

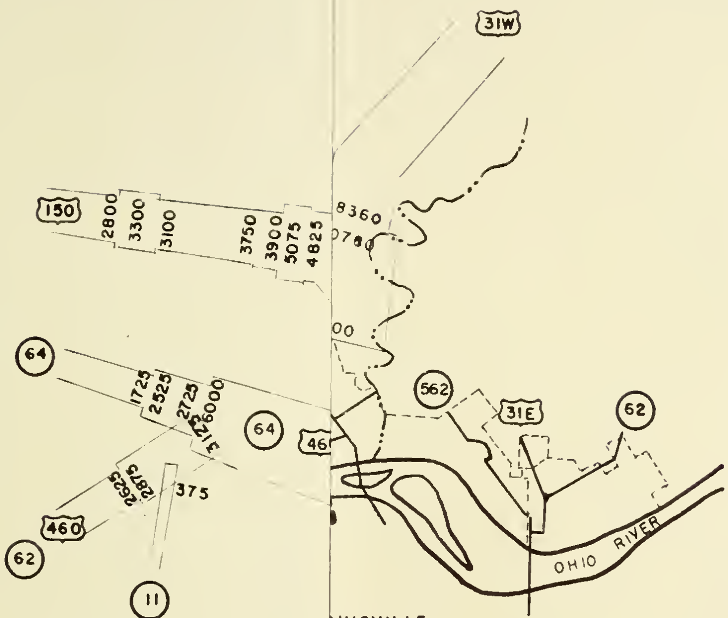
The Interstate highways are to be designed on the basis of the traffic estimated for the year 1975. Indiana has had on the average a 5.3 percent increase in traffic on state rural highways during the years 1946 to 1953 (29). Assuming this rate of increase will continue until 1975 there will be a 120 percent increase in traffic, or in other words the rural highway traffic in 1975 will be 220 percent of the 1952 traffic.

Assuming that the area photographed and being studied will be the route of the new highway it would appear that the new highway will run somewhere south of and roughly parallel to the present US #150. It would seem likely that there would be an interchange immediately to the west of the Knobstone escarpment. If this were the case traffic presently using highways US #150, Indiana #64, US #460, Indiana #62 and Indiana #11 would likely be diverted to a large extent to the new highway crossing of the escarpment. From the 1952 traffic flow map as shown in Figure 28, the total volumes of traffic on the above mentioned roads amounts to:

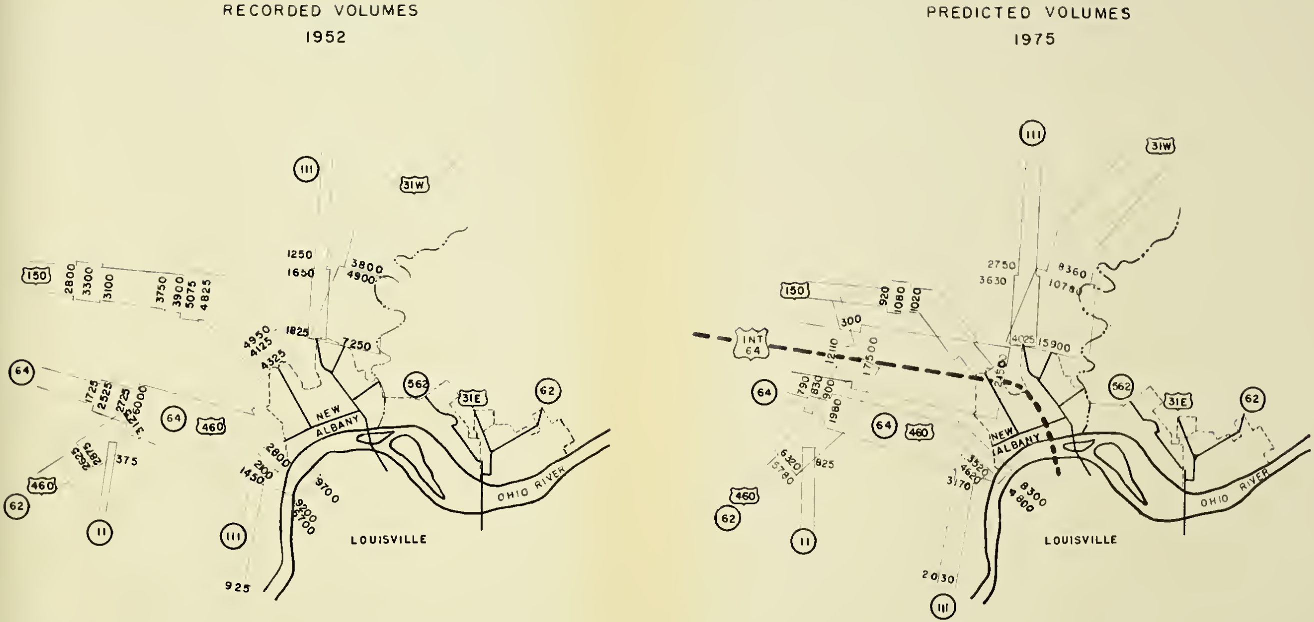
Indiana #64	- 6000 vehicles per day
US #150	- 3750 vehicles per day
1952 total	- 9750 vehicles per day

The predicted 1975 traffic would then be equal to 220/100 x 9750 = 21,500 vehicles per day. Estimating that

OLUMES



UISVILLE



TRAFFIC FLOW MAP
Yearly Average for 24 Hours

FIG. 28

75 to 80 percent of this traffic will want to use this new route it will have to carry

21,900 x 80 = 17,500 vehicles per day.

The Interstate standards specify that the design hourly volume (DHV) shall be the 30th highest hourly volume for 1975. To convert the average daily traffic (ADT) of 17,500 vehicles to DHV the AASHO manual gives the following formula (2, 3).

DHV (30th highest hour) = (K)(D)(ADT)

where K is DHV as a percent of ADT and

where D is one way volume in dominant direction

Average values selected from the AASHO manual are:

K = 15.5%, D = 67%.

Therefore the DHV = 17500 x .155 x .67 = 1820 vehicles per hour in one direction of travel.

The number of lanes then needed in any direction will be 1820/1000 = 2 using a recommended capacity per lane of 1000 vehicles per hour. This means there needs to be 2 lanes for each direction of travel or a total of 4 lanes.

Design Speeds

The Interstate highways are to have minimum speeds of 70 mph for flat topography, 60 mph for rolling topography, 50 mph for rugged topography, and 50 mph for urban routes. The knobstone escarpment would probably be classed as at least rolling and so a design speed of 60 seems to be practical.

Design Gradients

The Interstate policy suggests a grade of four percent for a design speed of 60 mph. As the grade on this project will have to climb approximately 450 feet, critical lengths of grade will have an effect. The AASHO manuals suggest the critical rise of 40 to 50 feet be used for design. For reduced grades suggested critical lengths of grade so as not to exceed the 40-50 foot critical rise are

1080 feet for 4 percent grade

1275 feet for 3½ percent grade

1560 feet for 3 percent grade

2000 feet for 2½ percent grade

3000 feet for 2 percent grade.

This means that to climb 450 feet it will be necessary to have breaks in grade in the form of flat stretches so that trucks can regain speed.

Degree of Curvature

The maximum allowable curvature depends upon passenger comfort and limiting values of superelevation. The AASHO policy recommends a limiting coefficient of side friction of f = 0.13 and a maximum superelevation rate of e = 0.10 (3). These two values combine to produce a maximum radius of curvature of 1043 feet, or a 5.5 degree curve. As the design is to be of such a nature as to permit good sight distance and to prevent roads from appearing to be kinked, it is often suggested that the maximum degree of curvature be 3.5 degrees.

Minimum lengths of curve used vary from 1000 feet to 2000 feet.

Width of Roadway Elements

Interstate standards specify the following widths for road elements (1):

1. 12 feet for traffic lanes
2. 10 feet for shoulders right of traffic
3. 6 feet for shoulders are permissible in rough terrain
4. 36 feet for medians in rural areas
5. 16 feet for medians in mountainous areas
6. 4 feet for medians in tunnels and bridges
7. 1 foot for clearance to curbs from normal 12 foot lanes
8. 3½ feet for clearance to walls from edge of pavement

Additional Indiana standards for divided highways are:

1. 4 feet for shoulders on left side of traffic
2. 60 feet for medians in rural areas

Bridge Widths and Clearance

It is recommended that for spans up to 150 feet that full shoulders be provided and that they be of deck construction. The overhead clearance on through trusses is to be at least 14 feet on the roadway including the useable shoulder.

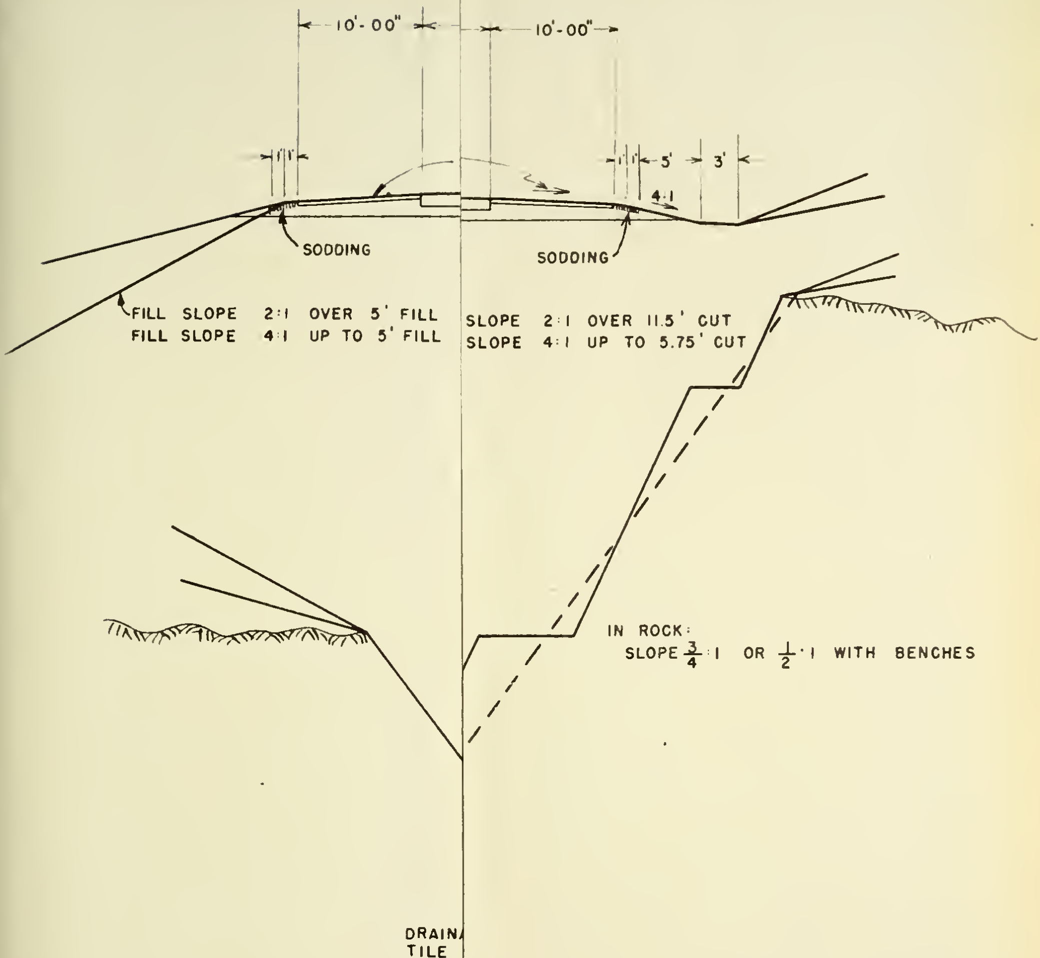
Side Slopes

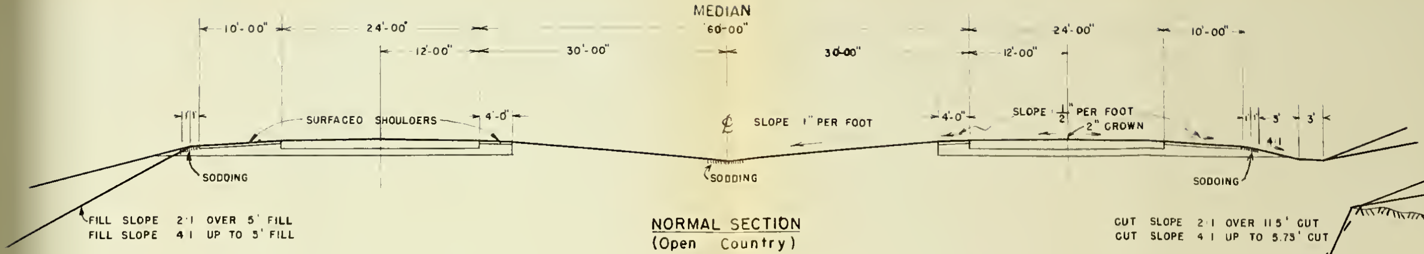
Interstate standards specify that side slopes shall be 4:1 or flatter if possible and not steeper than 2:1 except in rock (1). Indiana uses its own critical slopes for cut and fill sections. They specify for cuts a 4:1 slope up to 5.75 feet high and 2:1 over 11.5 feet. For fills, slopes are to be 4:1 up to 5 feet high and 2:1 over 5 feet high. For rock areas slopes can be much steeper, even up to a 1/2 or 3/4:1 slope (4 and 39). For deep rock cuts benches are often used wherever there is a natural layering or otherwise every 20 or 30 feet.

Width of Right-of-Way

All right-of-way is to have limited access for all roads with over 500 vehicles per hour (1). Interstate roads are to have a minimum width of right-of-way of 150 for a four lane divided highway without frontage roads. Additional right-of-way may be needed for deep cuts, fills and interchanges.

Typical cross sections which would be considered suitable for the Interstate highway #64 in the area studied are shown in Figure 29, 30, 31, and 32.


10'-00"
10'-00"
1' 1'
1' 1'
5'
3'
4:1
SODDING
SODDING
FILL SLOPE 2:1 OVER 5' FILL
FILL SLOPE 4:1 UP TO 5' FILL
SLOPE 2:1 OVER 11.5' CUT
SLOPE 4:1 UP TO 5.75' CUT
IN ROCK:
SLOPE $\frac{3}{4}$:1 OR $\frac{1}{2}$:1 WITH BENCHES
DRAIN
TILE



NORMAL SECTION
(Open Country)

FIG. 29

DEEP ROCK CUT SECTION

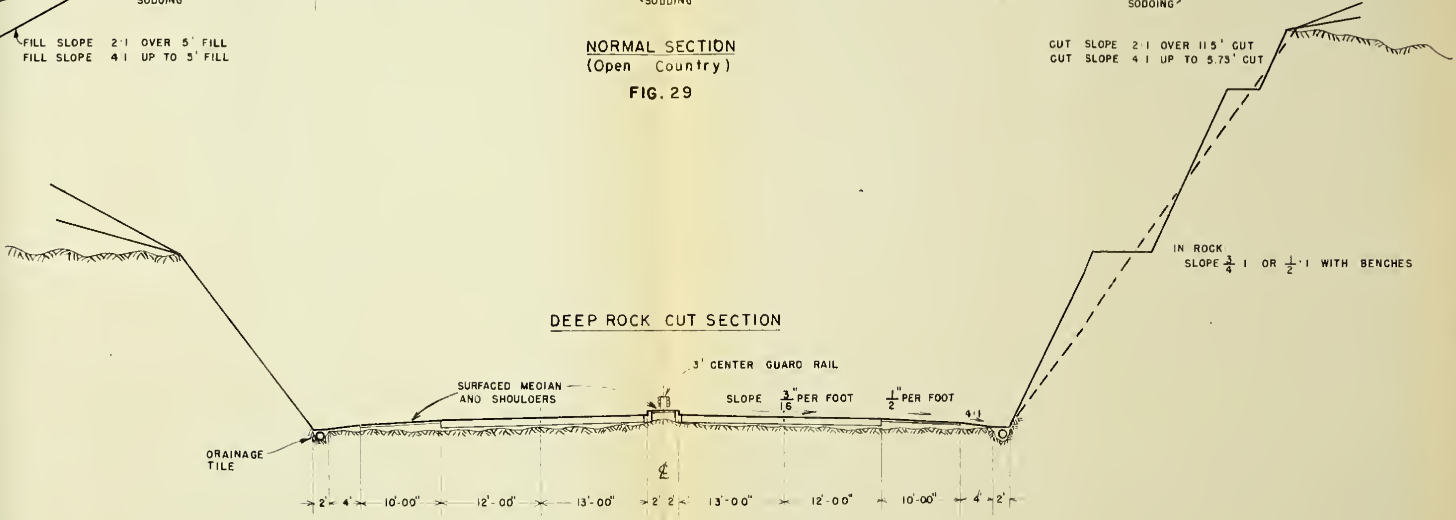
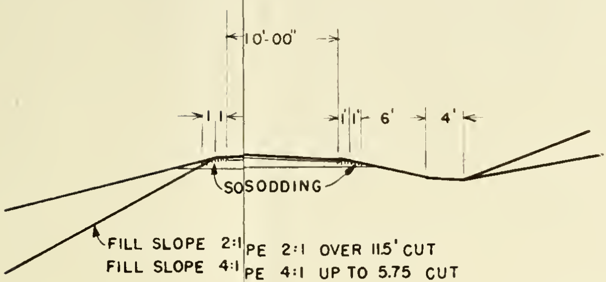


FIG. 30

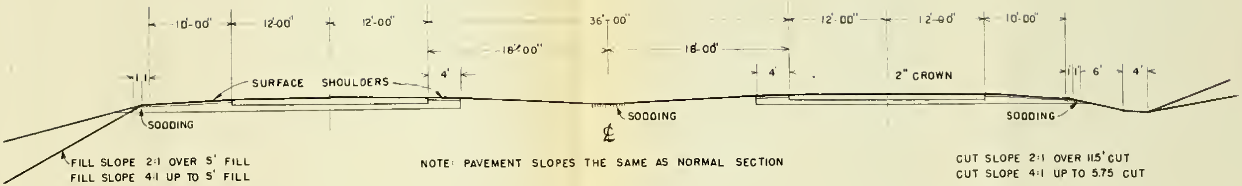
TYPICAL ROAD CROSS SECTIONS
INTERSTATE ROUTE 64
INDIANA



NTER 5" BELOW GRADE

CURBS PLACED 1'
PAVEMENT EDGE

TYPICAL ROAD CROSS SECTIONS
(Continued)



URBAN SECTION

FIG. 31

TUNNEL SECTION

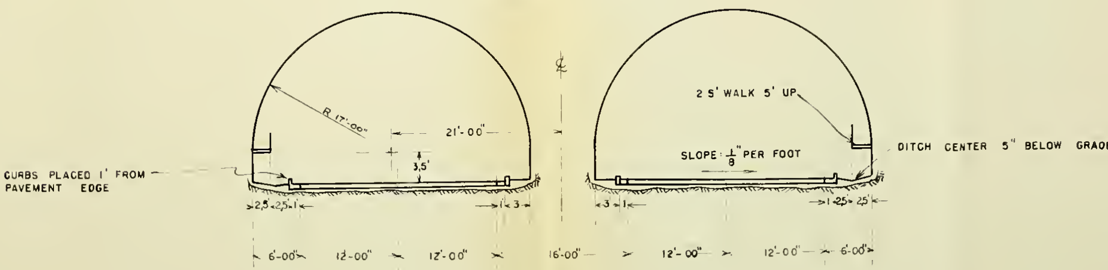


FIG. 32

Table 3

Summary of Design Standards

Element	Maximum	Minimum	Value Selected
Design capacity vehicles/lane	1200	1000	1000
Design speed	60 mph	50 mph	60 mph
Degree of curvature	5.5°	1000 ft. length	3.5°
Gradient percent	4 or 5	-	4
Critical length of grade	40	50 foot rise	
Lane width (feet)		12	12
Shoulder width outside (feet)		10	10
Shoulder width inside (feet)		4	4
Curb clearance (feet)		1	1
Wall clearance (feet)		$3\frac{1}{2}$	$3\frac{1}{2}$
Median rural (feet)	60	36	60
Median deep cut (feet)		4	4
Median in restricted area (feet)		16	16
Slope: Fill under 5.0 feet		4:1	4:1
Fill over 5.0 feet		2:1	2:1
Slope: Cut up to 5.75 feet		4:1	4:1
Cut 5.75 to 11.5 feet		3:1	3:1
Cut over 11.5 feet		2:1	2:1
Right-of-Way width		150	200

Route Design Sections

The knowledge of terminal and intermediate control points is necessary in order to select a specific route that will serve all areas effectively. Any route can be subdivided into design sections so that each section because of a similar topographic condition can be considered a complete design unit of itself. Plate 4 shows 3 sections for the proposed Interstate Highway #64 near New Albany. The 3 sections are: the Little Indian Creek section, the Knobstone section and the New Albany section.

The Little Indian Creek section would run from a crossing of Big Indian Creek along the Little Indian Creek at a gently climbing grade to a point near the junction of Old Vincennes and Banet and Duffy roads. This route because it would generally follow a river valley on the Norman Upland would present few difficulties to road builders.

The Knobstone Section starts from the above road junction and must climb up 140 feet to the top of the escarpment before dropping about 450 feet down the rugged face of the escarpment to the valley of Falling Run Creek just on the north edge of New Albany. This section which was the area mapped and studied for the proposed road is the most rugged and difficult to cross because of its steepness and entirely rock nature. The Knobstone section is a natural design unit as there likely will need to be an interchange just to the west of the escarpment to collect traffic from the various

roads which now have junctions there. The eastern end of the Knobstone section also is a natural place for an interchange as there are several major roads coming into New Albany from the north and Interstate road #65 from Indianapolis will probably pass through this area on its route to the proposed bridge to Louisville. The Knobstone section will be about four miles long as set up in these proposed highway sections.

At the eastern end of the Knobstone section there is the New Albany Urban section. This is a very flat section in the Ohio River valley and runs from the north edge of New Albany across the narrowest part of town to the proposed bridge site on the Ohio River. A probable line would follow near E. 10th or E. 11th Streets.

The site of the proposed bridge about 7 or 8 blocks west of the existing K. and I.T. Railroad bridge actually controls the routing of the proposed road back to the west side of the escarpment because if it were east or west of the presently proposed site, lower cost rural routes could be found for the road east or west of New Albany resulting in different approaches to the escarpment.

The three design sections are not intended to be rigid as to the terminal points of each section, but are intended to be guides in designing each unit. Although the Knobstone section was the area mapped for this problem, the mapping did overlap onto each of the adjacent sections.

Route #1 - Tunnel Route

General Routing

This route as shown on the plan starts about 3000 feet north and 1000 feet east of the junction of Old Vincennes, Banet and Duffy roads. By following the contours somewhat it descends from the 840 foot elevation at the start to about the 780 foot elevation to cross the Little Indian Creek valley at a point about 1500 feet downstream from the present bridge on US #150. After this crossing of the creek the road swings slightly south to head up a natural draw into the highest part of the escarpment at an elevation of about 850. About 1800 feet from the creek the road comes to the west end of the proposed tunnel. The tunnel will be straight and on a grade and will emerge at about the 710 foot level. At its exit the road is in a steep sided valley. It follows the south side of this valley for about 500 feet and then curves left to cross to the other side of the valley to take advantage of gentler slopes. It requires about a 60 foot fill to cross this valley. The road then follows the descending contours staying on the north side of the valley, which is a valley of a branch of Falling Run Creek. When the road reaches the 520 foot level it must cross over highway US 150. The new road should pass over on a double overhead bridge which also is on a gentle curve. After crossing US 150 the road will run parallel to and about 500 feet north of Daisy Lane. At a point 1100 feet east of US 150 the road will cross

Franklin Drive at grade level and it is proposed to have no crossing for Franklin but rather to make a Cul-de-Sac on both sides of the new road and construct a new street on the north side of the highway to connect Franklin Drive to Green Valley road. About 1500 feet east of Franklin Drive the new highway will cross over Green Valley road on a double set of bridges. About 800 feet east of Green Valley road the highway will swing towards the south and cross Falling Run by means of a large culvert. The highway should also pass under Daisy Lane. It will be necessary to raise the grade on Daisy Lane here by about 15 feet. The highway then passes behind the WKLO Radio towers and follows at about ground level along Falling Run into New Albany. The eastern terminal point for the Knobstone section will be at a point about 500 feet north of where Falling Run crosses Graybook Road.

Length of Line

Line begins at Station	20,000	
Line ends at Station	42,800	
Total length	22,800	feet
or Total length	4.34	miles

Plate 5 is a plan of proposed Route #1. Plate 6 is the profile of proposed Route #1.

Table 4

Route #1 Horizontal Alignment

Station to Station	Tangent Length (feet)	Curve Length (feet)	Degree of Curve (degrees)
20000 - 20930	930		
20930 - 21960		1030	2.5 Left
21960 - 23290	1330		
23920 - 24250		960	2.5 Right
24250 - 25330	1080		
25330 - 26050		720	3.3 Right
26050 - 28220	2170		
28220 - 29170		950	3.3 Left
29170 - 30230	1060		
30230 - 31100		870	2.5 Right
31100 - 33250	2150		
33250 - 35020		1770	1.5 Left
35020 - 37840	2820		
37840 - 40330		2490	2.5 Right
40330 - 42,800	2470		

Table 5

Route #1 Vertical Alignment

Station to Station	Distance (feet)	Grade (Percent)
20000 - 20600	600	-2.0
20600 - 21300	700	+2.0
21300 - 22900	1600	-3.0
22900 - 23900	1000	-1.0
23900 - 25500	1600	+1.0
25500 - 26000	500	-2.0
26000 - 28200	2200	-3.0 (tunnel)
28200 - 29150	950	-1.5
29150 - 31200	2050	-4.0
31200 - 32200	1000	-1.6
32200 - 33500	1300	-4.0
33500 - 34500	1000	-0.0
34500 - 35650	1150	-5.0*
35650 - 37300	1650	-0.0
37300 - 38625	1325	-3.0
38625 - 39300	675	0.0
39300 - 41300	2000	+2.0
41300 - 42800	1500	-2.0

*It was impossible in this problem to adhere completely to maximum feet of climb on critical grades and to always keep the grade under 5 percent because of excessive amounts of earthwork necessary in cut sections.

Median Width

On the upland areas from the start of this section at station 20000 to station 25300 a 60 foot median should be used. From station 25300 to station 26000 which is in rock the median should be reduced to 16 feet. The center lines of the two roadways for the tunnel section running from 26000 to 28100 should be kept the same as for a 16 foot median. The median from the tunnel exit at 28100 to station 30500 should be kept down to 16 feet because of the deep rock fill and side hill location of the road in places. From station 30500 to the end of the section at station 42800 a 36 foot median could be used as housing is not too dense.

Width of Right-of-Way

The predominantly rural area from station 20000 to 26000 should have a 250 foot wide right-of-way because the land value does not seem too high. The tunnel section from station 26000 to 28100 should be protected by a 200 foot right-of-way. From the tunnel exit at station 28100 to station 30000 because of the deep fill required a 300 foot right-of-way will be required. From station 30000 to the end of the line at station 42800 a 200 foot right-of-way should serve.

Building Removals

There are approximately 16 houses that will have to be sold for removal. There are also about 6 barns and some other

minor structures that need to be removed.

Table 6

Route #1, New Road Structures Required

Station	Requirement	Size	Purpose
20500	culvert	6 feet by 150 feet	drainage
21600	single bridge	30 feet by 150 feet	Banet Road crossing
24500	double bridge	2 at 40 feet by 60 feet	Little Indian Creek crossing
26000 - 28100	tunnel	34 feet wide twin tubes	reduce cut
31700	culvert	3 feet by 140 feet	drainage
34300	double bridge	2 at 40 feet by 60 feet	Paoli Pike underpass
3700	culvert	6 feet by 130 feet	drainage
37180	double bridge	2 at 40 feet by 40 feet	Rural road underpass
38400	culvert	20 feet by 150 feet	Falling Run crossing
39100	single bridge	30 feet by 100 feet	Daisy Land crossing

Earthwork Quantities

Assuming that the majority of the excavation is in rock a division of costs between earth and rock quantities can be made. The sections station 20000 to station 24000 and also the section from station 3500 to station 42800 will be considered soil and the remainder of the line will be considered rock work. From the table of Earthwork Quantities

(Appendix B) the volumes of soil and rock for this route are summarized in Table 7. The quantities shown are not altered by a swell or shrinkage factor because the grade is not considered a final grade. The rock cut section which appears to need fill can make use of tunnel yardage to balance out because it is very close to where the fill is needed as the profile for Route #1 shows.

Table 7

Route #1 Earthwork Quantities

Station to Station	Soil (cu. yds.) Cut	Fill	Borrow	Rock (cu. yds.) Cut	Fill	Borrow
20000 - 24000	47038	69330	22292			
24000 - 26000				358262 *105000	426844	-
26000 - 28100						
28100 - 35000						
35000 - 42800	54349	220444	166095			
Total	101387	289774	188387	463262	426844	

Route #2 Deep Cut Near Floyds Knobs

General Routing

This line starts 1500 feet north of the junction of Old Vincennes, Duffy and Banet roads. It parallels Little Indian Creek for about 2500 feet and is at about the 780 foot level. It then crosses Little Indian Creek utilizing a natural draw and climbs to a high point of about 860 feet. Immediately upon crossing the creek the road starts to enter a deep cut which is about 25 feet deep for 2000 feet and then increases in depth until it is about 140 feet deep at the eastern edge of the escarpment. The cut increases in depth because it is necessary to have the road descend to about the 740 foot level of the "Knobs" on the east side of the escarpment. Upon leaving the face of the escarpment the road stays on the north side of the same tributary of Falling Run that the "Tunnel Route" follows. This route brings the road due east from the escarpment until it is close to highway US 150 where it swings south and parallels the highway and descends to about the 540 level. It then turns due east again and crosses over highway US 150 by means of a double overhead structure. From this point the road would duplicate the tunnel route to the north side of New Albany.

Plate 5 is a plan of proposed Route #2. Plate 7 is the profile of proposed Route #2.

Length of Route #2

Line begins at Station = 20,000

Line ends at Station = 43,430

Total Length = 23,430 feet

or Total Length = 4.45 miles

Table 8

Route #2 Horizontal Alignment

Station to Station	Tangent Length (feet)	Curve Length (feet)	Degree of Curve (degrees)
20000 - 22470	2470		
22470 - 23330		860	1.5 Right
23330 - 25500	2170		
25500 - 26400		900	1.5 Left
26400 - 27170	770		
27170 - 28770		1600	1.5 Right
28770 - 29930	1160		
29930 - 30600		670	1.5 Left
30600 - 31350	750		
31350 - 32600		1250	3.3 Right
32600 - 33480	880		
33480 - 35280		1800	2.5 Left
35280 - 38470	3190		
38470 - 40960		2490	2.5 Right
40960 - 43430	2470		

Table 9

Route #2 Vertical Alignment

Station to Station	Distance (feet)	Grade (percent)
20000 - 22400	2400	0.0
22400 - 23600	1200	1.0
23600 - 25350	1750	4.0
25350 - 25900	550	0.0
25900 - 27500	1600	-3.0
27500 - 29300	1800	-4.0
29300 - 30100	800	-2.0
30100 - 31300	1200	-5.0
31300 - 31900	600	-2.0
31900 - 34200	2300	-4.0
34200 - 35100	900	-2.0
35100 - 36400	1300	-4.0
36400 - 37930	1530	0.0
37930 - 39255	1325	-3.0
39255 - 39930	675	0.0
39930 - 41930	2000	2.0
41930 - 43430	1500	-2.0

Median Width

On the upland section from the beginning at station 20000 to station 23300 a 60 foot median should be used. From station 23300 to station 25500 a 36 foot median should be used because of a 40 foot deep fill and cuts in rock of 20 to 30 feet. The deep rock cut section from station 25500 to station 28000 will necessitate the use of a median of 4 feet because of the high cost of rock excavation. From station 28000 to station 28800 a deep rock fill will require that the median be kept to 36 feet. The remainder of this route from station 28800 to station 43430 will be in an urban setting and a 36' median will be used for preliminary design.

Width of Right-of-Way

The predominantly rural area west of the escarpment from station 20000 to station 25500 is low value property and a 250 foot right-of-way should be used. The deep cut section from station 25500 to station 28200 will require a right-of-way 300 feet wide. The remainder of the line from station 28200 to station 43430 will be enclosed by a 200 foot right-of-way.

Building Removal

There are about 16 houses that will be within the right-of-way and must be removed. There are also about 12 barns and minor structures which must be removed also.

Table 10

Route #2 New Road Structures Required

Station	Requirement	Size	Purpose
20850	culvert	6 feet by 150 feet	creek drainage
21200	culvert	6 feet by 150 feet	creek drainage
23950	double bridge	2 at 40 feet by 60 feet	Little Indian Creek crossing
27700	single bridge	30 feet by 200 feet	Old Mill Road overpass
29800	culvert	6 feet by 300 feet	creek drainage
31100	culvert	4 feet by 150 feet	creek drainage
32050	culvert	4 feet by 150 feet	creek drainage
35050	double bridge	2 at 40 feet by 60 feet	Paoli Pike underpass
37800	double bridge	2 at 40 feet by 40 feet	Green Valley Road underpass
39100	culvert	20 feet by 150 feet	creek crossing
39800	single bridge	30 feet by 100 feet	Daisy Lane overpass

Earthwork Quantities

The majority of the earthwork will be in rock and some of the flat upland and flat lowland will be in soil areas. It appears that the prominent ridge is rock and it was therefor assumed that from station 24300 to station 33600 is rock excavation and from station 20000 to station 24300 is soil and also from station 33600 to station 43430 there is soil primarily. Shrinkage and swell have not been considered

because of the preliminary nature of this design. The section from Station 20000 to 24300 will not require borrow because as the profile of Route #2 shows the deep fill is next to a rock cut area with excess cut. The section from Station 33600 to Station 43430 will require borrow because the fill area is too far from the deep cut area.

Table 11

Route #2 Earthwork Quantities

Station to Station	Soil (cu. yds.) Cut	Fill	Borrow	Rock (cu. yds.) Cut	Fill	Borrow
20000 - 24300	101173	266426	-			
24300 - 33600				1534750	470722	-
33600 - 43430	99734	520415	420681			
Total	200907	786841	420681	1534750	470722	-

Route #3 Deep Cut Near Old Vincennes Road

General Description

This line starts 1000 feet west of the junction of Old Vincennes, Banet and Duffy roads. The route heads easterly and crosses Little Indian Creek and Old Vincennes road on a gentle curve. The route crosses over this road on a double overhead structure and climbs from the 750 foot level to the 820 foot level along the Old Vincennes road. The proposed line stays on the north side of the old road for 5000 feet. At about the junction of Old Vincennes and Quarry roads this route starts descending by means of a cut. Old Vincennes road will pass over the new route at this point. The descent from the 820 foot level to the 580 foot level is almost at constant grade but is accomplished by deep cuts of 60 feet, 140 feet, 90 feet, and 100 feet through rocky spurs jutting out from the escarpment. This involves three crossings of the old road and a fill of 60 feet across a tributary of Falling Run. When the road is down to the 580 foot level it remains fairly level until it crosses highway US 150. This level section is about 500 to 1000 feet from and roughly parallels Captain Frank Road. This level stretch of road intersects four spurs of the Knobs necessatating four cuts and four fills of from 20 to 50 foot depth. The route will cross highway US 150 and Green Valley Road on double overhead structures and will remain elevated on a fill about 15 feet

high until it crosses Bond Road. Bond Road will be closed by this crossing. This routing has the new road crossing highway US #150 and Green Valley Road about 400 feet north of the junction of these two roads. This route will cross over Falling Run into the creek's lowland which lie at about 440 feet elevation. The terminus for this route is just west of the crossing by Falling Run of Graybrook Road.

Length of Route #3

Line begins at Station	=	20,000
Line ends at Station	=	43,880
Total Length	=	23,880 feet
or Total Length	=	4.53 miles

Plate 8 is a plan of proposed Route #3. Plate 9 is the profile of proposed Route #3.

Table 12

Route #3 Horizontal Alignment

Station to Station	Tangent Length (feet)	Curve Length (feet)	Degree of Curve (Degrees)
20000 - 20290	290		
20290 - 22200		1910	1.5 Left
22200 - 22980	780		
22980 - 23950		970	1.5 Right
23950 - 25430	1480		
25430 - 26400		970	2.5 Right
26400 - 29100	2700		
29100 - 32160		3060	2.5 Left
32160 - 33800	1640		
33800 - 35280		1480	2.5 Right
35280 - 36820	1590		
36870 - 37600		730	2.5 Left
37600 - 38720	1120		
38720 - 39630		910	1.5 Right
39630 - 42180	2550		
42180 - 43780		1600	2.5 Right

Table 13

Route #3 Vertical Alignment

Station to Station	Distance (feet)	Grade (percent)
20000 - 20500	500	-0.5
20500 - 23000	2500	+2.5
23000 - 24100	1100	+1.0
24100 - 25050	900	-2.0
25050 - 25900	850	+2.0
25900 - 27000	1100	-1.0
27000 - 29000	2000	-3.0
29000 - 31600	2600	-2.0
31600 - 34200	2600	-4.0
34200 - 34700	500	-3.0
34700 - 35600	900	1.0
35600 - 37500	1900	-0.5
37500 - 39600	2100	-4.0
39600 - 42075	2475	-2.0
42075 - 43800	1725	0.5

Table 14

Route #3 Structures Required

Station	Requirement	Size	Purpose
21000	double bridge	2 at 40 feet by 60 feet	Indian Creek crossing
21900	double overhead	2 at 40 feet by 75 feet	Old Vincennes Road underpass
23700	culvert	6 feet by 150 feet	creek drainage
25200	double overhead	2 at 40 feet by 40 feet	rural road underpass
26150	single bridge	30 feet by 120 feet	Old Vincennes Road overpass
30150	single bridge	30 feet by 150 feet	Old Vincennes Road overpass
30850	single bridge	30 feet by 150 feet	Old Vincennes Road overpass
31550	single bridge	30 feet by 120 feet	Old Vincennes Road overpass
32700	culvert	10 feet by 500 feet	stream drainage
34600	culvert	6 feet by 300 feet	stream drainage
36050	double overhead	2 at 40 feet by 80 feet	rural road underpass
39600	double overhead	2 at 40 feet by 80 feet	Highway 150 underpass
40050	double overhead	2 at 40 feet by 60 feet	Green Valley Road underpass
41800	double bridge	2 at 40 feet by 50 feet	Falling Run crossing

Width of Right-of-Way

From station 20000 to station 27500 which is in predominantly a low value rural area a 250 foot right-of-way should be used. From station 27500 to station 33500 an area of deep rock cuts and fills a right-of-way of from 300 to 350 feet will be required. From station 33500 to the end of the line at station 23880 a right-of-way of 200 feet should be used as this area is more suburban in nature.

Width of Median

From station 20000 to station 27500 a 60 foot median should be used. From station 27500 to station 32600 a 4 foot median can be used because of the deep rock cuts. The suburban section from station 32600 to the end should have a 16 foot median.

Building Removal

There are about 12 houses that will have to be moved to clear the right-of-way. About 4 barns and several minor structures must be removed. The most expensive removal job will be two motel properties near the junction of Highway US 150 and Green Valley Road.

Route #3 Earthwork Quantities

From an inspection of the profile of Route #3 it appears that the earthwork would be too excessive and the volumes were therefore not calculated.

CHAPTER VIII

COST BENEFIT COMPARISON OF TWO ROUTES

Method of Analysis

A benefit analysis for highway improvements in terms of road user costs is a comparison of annual costs of two or more alternatives. The annual road user costs include costs of maintenance, improvement and vehicle operation. The comparison is expressed arithmetically as a benefit ratio. The numerical ratio is an index of the relative merit of one route over another(43).

The annual road user costs is a total of both vehicle operating cost and the value on travel time.

The annual highway cost includes capital and maintenance costs. The annual capital cost is the amount of money required to amortize the construction costs including the interest accumulating.

$$\text{Benefit Ratio} = \frac{\text{Benefits}}{\text{Costs}} = \frac{\text{Difference in Road User Costs}}{\text{Difference in Highway Costs}}$$

Where Road User Costs = 365 A.L.U.

Where A = annual average daily traffic

Where L = length of section miles

Where U = combined operating and time costs

Highway Costs = $(C_1K_1 \; C_2K_2 \; C_3K_3) \quad M$

Where C = capital cost of items

Where K = capital recovery factors for a rate of interest and amortization of items for its average life

Where M = annual maintenance costs

Table 15

Construction Cost Estimate

for Route #1 - Tunnel Route

Item	Units	Unit Cost (dollars)	Total Cost (dollars)
Right-of-Way	4.33 miles	$ 60,000(a)	$ 260,000
Surface and Base	3.93 miles (b)	170,000(a)	668,000
Earth Cut Volume	101,387 cu. yds.	0.40(c)	40,554
Earth Borrow	188,387	0.40(c)	75,358
Rock Excavation	358,262	1.25(d)	447,828
Bridges 40 foot width	320 lineal feet	700(a)	224,000
Bridges 30 foot width	310 lineal feet	525(a)	162,750
Tunnel Construction	2100 lineal feet	2,973(e)	6,243,450
Drainage Culverts	570 lineal feet	20(f)	1,400
House Removals	20 houses	10,000(g)	200,000
			$8,333,337

(a) Based on cost summarized Indiana Needs Study (12).

(b) Less than 4.33 included in tunnel cost.

(c) Based on Engineer News-Record cost summary (9).

(d) Based on verbal estimate of cost of rock work in Indiana.

(e) Based on cost per lineal foot of Fort Pitt Tunnel (52).

(f) Based on verbal estimate of 24-inch corrugated steel pipe

(g) Based on estimate of house values in area.

Route #1 Road User and Annual Costs

Annual average traffic for period $\frac{7800 \quad 17500}{2}$ = 12,150

Annual Average Equivalent traffic (Ae) including 10 percent

trucks = 10935 (1215X3) = 14,580

L = 4.34 miles

0-3 percent grades = 3.50 miles

3-5 percent grades = .84 miles

U = operating costs for a 4 lane divided highway

0-3 percent " = 7.35 cents

3-5 percent = 7.64 cents

365 X 14,580 X 3.50 X .0735	=	$1,367,677
365 X 14,580 X .84 X .0764	=	288,436
		$1,656,113

Table 16

Route #1 Annual Cost of Capital Expenditure

Item	Estimated Life	Cost	K percent*	Annual Cost
Pavement	20 years	$ 668,100	.0641	$ 42,825
Row	100 years	260,000	.0273	5,200
Grading	40 years	563,737	.0398	22,436
Tunnel	70 years	6,243,450	.0304	189,801
Bridges	40 years	386,750	.0398	15,392
				$275,654

*Based on estimated 2½ percent interest rate (43).

The annual maintenance costs for 4 lane Interstate rural highways in Indiana are approximately $1,090 per mile (12).

Maintenance cost = 1,090 x 4.34 = $4,731.00.

Route #2 Road User and Annual Costs

Average equivalent annual traffic (Ae) = 14,580 vehicles per day.

L value = Line is 4.45 miles long.

Length with 0-3 percent grades = 2.87 miles

Length with 3-5 percent grades = 1.58 miles

V value = operating costs

Grades 0-3 percent = 7.35 cents

Grades 3-5 percent = 7.64 cents

365 x 14,580 x 2.87 x .0735 = $1,121,997

365 x 14,580 x 1.58 x .0764 = 642,727

Yearly Capital Costs $1,764,714

Table 17

Route #2 Annual Cost of Capital Expenditure

Item	Estimated Life	Cost	K for 2½ percent	Annual Cost
Pavement	20 years	$ 755,000	.0641	$ 48,395
Right-of-Way	100 years	267,000	.0273	7,289
Grading	40 years	2,127,011	.0398	84,655
Bridges	40 years	399,000	10398	156,219

Maintenance cost = $1,090 x 4.45 = $4,850.00.

Table 18

Construction Cost Estimate

for Route #2 - Deep Cut Near Floyds Knobs

Item	Units	Unit Cost (dollars)	Total Cost (dollars)
Right-of-Way	4.45 miles	$ 60,000(a)	$ 267,000
Surface and Base	4.45 miles	170,000(a)	755,000
Earth Cut	200,900 cu. yds.	.40(c)	40,360
Earth Borrow	420,681 yds.	.40(c)	168,273
Rock Excavation	1,534,750 yds.	1.25(d)	1,993,438
Bridges 40 foot width	320 lineal feet	600(a)	192,000
Bridges 30 foot width	360 lineal feet	525(a)	189,000
Culverts	900 lineal feet	20(f)	18,000
Culvert 20 feet wide	150 lineal feet	30(f)	4,500
House Removal	16 houses	10,000(g)	160,000
Barn Removal	12 barns	2,000(g)	24,000
			$3,736,571

Benefit Ratio of Route #1 - Tunnel Route - with respect to Route #2

Deep Cut Near Floyds Knobs: =

$$\frac{\text{Benefits}}{\text{Costs}} = \frac{\text{road user cost deep cut - road user costs tunnel}}{\text{Annual cost tunnel - annual cost deep cut}}$$

$$= \frac{1,764,714 - 1,656,113}{280,385 - 161,069} = \frac{108,601}{119,316} = 0.91.$$

CHAPTER IX

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary of Work

1. Reconnaissance of the Knobstone Escarpment was carried out with the aid of the following sources of information: U. S. Geological Survey $7\frac{1}{2}$ minute quadrangle sheets, U. S. Department of Agriculture Adjustment Administration 1/20000 scale aerial photography and mosaics of Floyd County, Indiana State Highway Department 1/7200 scale photography and flight line mosaics, Indiana State Highway Department plan and profile of route US #150, Engineering Soils and Drainage maps of Floyd County made by the Joint Highway Research Project at Purdue University, New Albany street map, U. S. Geological Survey transit traverse notes, U. S. Geological Survey level notes, U. S. Coast and Geodetic Survey, Triangulation Diagram of Indiana, drainage, physiographic and geological maps and descriptions from the Indiana Handbook of Geology.
2. Field surveys were conducted to obtain 110 picture point elevations and 43,100 feet of chaining in 34 different lines for horizontal control and 13 coordinate stations were located and identified and 2 additional ones were surveyed for model assembly control.
3. A check profile was surveyed by an Indiana State Highway Department crew in order to obtain elevations every 20 feet along a 7000 foot survey line.

4. A topographic map of an area 12000 feet wide by 20750 feet long was made at a scale of 200 feet-per-inch with a 10 foot contour interval. The map was made with a Kelsh plotter. Glass diapositive plates of the aerial photographs were made from photography taken for the Indiana Highway Department by Abrams Aerial Survey Corporation.
5. A vertical accuracy comparison was made between the profile made from the photogrammetric contour maps and the check line profile using the National Standards of Map Accuracy as the criteria. A horizontal accuracy check was made against the check line profile notes and U. S. Geological Survey traverse distances. The horizontal accuracy check was made according to Engineering and National Standards of Map Accuracy.
6. Three highway center lines were selected and drawn on the topographic map using Interstate standards of alignment. Profile drawings were also made of these three center lines and grades were selected staying as close as possible to Interstate maximum percent grades.
7. Earthwork volumes were estimated for two of the routes by multiplying the average depth of cut or fill per 100 foot stations by the roadway cross section area applicable at each station.
8. For the two lines for which earth quantities were calculated, rough estimates of the relative costs of the two

routes were made; including cost of right-of-way, grading, base and pavement, rock excavation, bridge structures and maintenance. Sources of cost data were the Engineering News Record and Indiana State Highway Department manuals.

9. For the two lines for which costs were estimated a Cost-Benefit analysis comparing these two routes was made using the procedure of the American Association of State Highway Officials "Planning and Design Policies on Road User Benefit Analysis for Highway Improvements."

Conclusions

1. The reconnaissance study was useful to gain familiarity with the area and to select two general alignments which were further developed.
2. The topographic map at 200 feet-per-inch was very satisfactory for preliminary study of alternate routes.
3. The vertical accuracy of the plotted map was within National Standards of Map Accuracy for the line tested.
4. The horizontal accuracy appears to be very close to National Standards of Map Accuracy although the number of points tested was too few to be conclusive.
5. The proposed cost of Route #1 - Tunnel Route will cost approximately $8,333,337.
6. The proposed cost of Route #2 - Deep Cut Route near Floyds Knobs will be approximately $3,736,531.

7. The Cost-Benefit ratio of Route #1 over Route #2 is 0.91.
8. The use of state plane coordinates was of great value for model assembly and accuracy checking.
9. The accuracy of contours in areas of dense trees is open to question.
10. The accuracy of plotted positions of model 363-4 is open to question because of no coordinate control being used for its assembly into the map.
11. The vertical accuracy of model 366-7 is open to question due to a five foot disagreement between level data at a road intersection.
12. The procedure of plotting models on separate boards and then tracing them onto linen results in the loss of some detail and accuracy.
13. The plotting of the models on separate boards results in unnecessary plotting duplication.
14. An operator can be trained to plot with a Kelsh Plotter in 3 or 4 weeks practice.

Recommendations for Future Work

1. For preliminary design in rural areas a mapping scale of from 200 feet-per-inch to 400 feet-per-inch would be suitable. For preliminary design in dense urban areas scales of from 200 feet-per-inch to 100 feet-per-inch should be used.
2. The survey of picture point control should be carried out before taking the aerial photography so that well defined points will be seen in the photographs.

3. The survey of horizontal control should always be carried out using connected, continuous traverses throughout the entire working area particularly if they are to be used for final location line surveys.

4. The length of horizontal control lines should be at least as long as 25 percent of the width of the model to obtain better scale solutions in plotting.

5. The number of vertical control points should be 6 as a minimum and 10 or more if the points can't be ideally placed near the corners of the stereomodel.

6. The use of state plane coordinates should always be used even if there are only two coordinate positions available for the establishment of a coordinate grid.

7. The use of stereotemplets should be used for model assembly control unless there are at least two coordinate points useable in each stereomodel.

8. The mapping procedure can be considerably improved and speeded by plotting directly onto a continuous roll of dimensionally stable plastic scribing paper instead of on cardboard and then tracing onto linen.

9. Horizontal control should be plotted on the drawing medium before plotting is done if a continuous roll of plotting film is used.

10. Accuracy check profiles should be run across natural topography in fields rather than near or on roads because of difficulty seeing and plotting along roads.

11. The accuracy check of any map should be done in smaller

checks in several areas rather than one large check.

12. Plotting of small details such as power poles, fence posts, dense housing areas in detail should be eliminated from preliminary mapping procedure.

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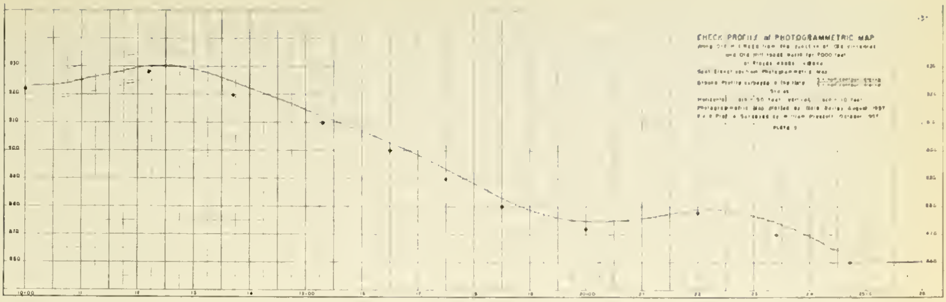
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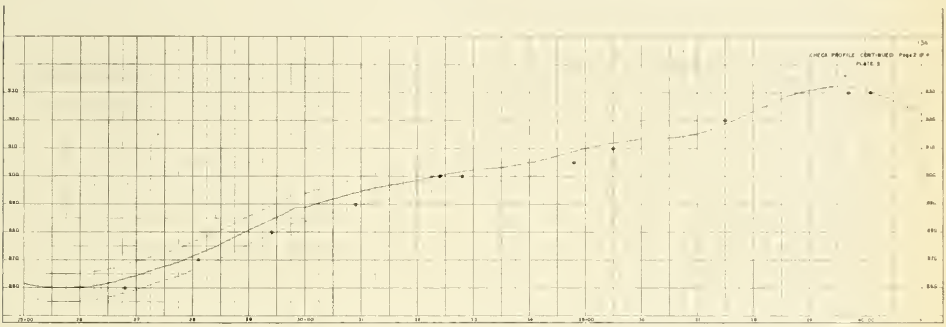
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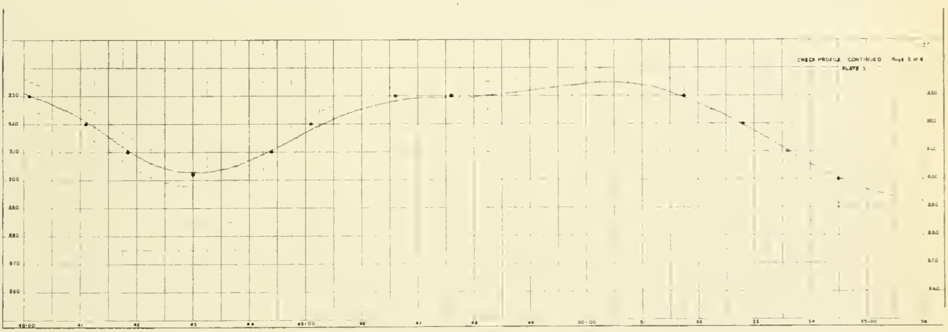
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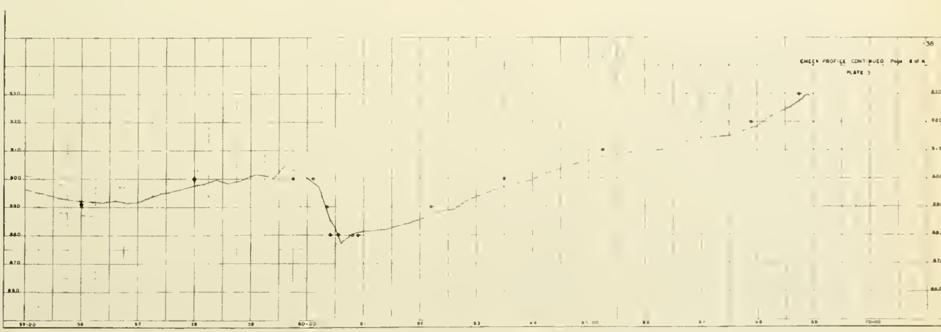
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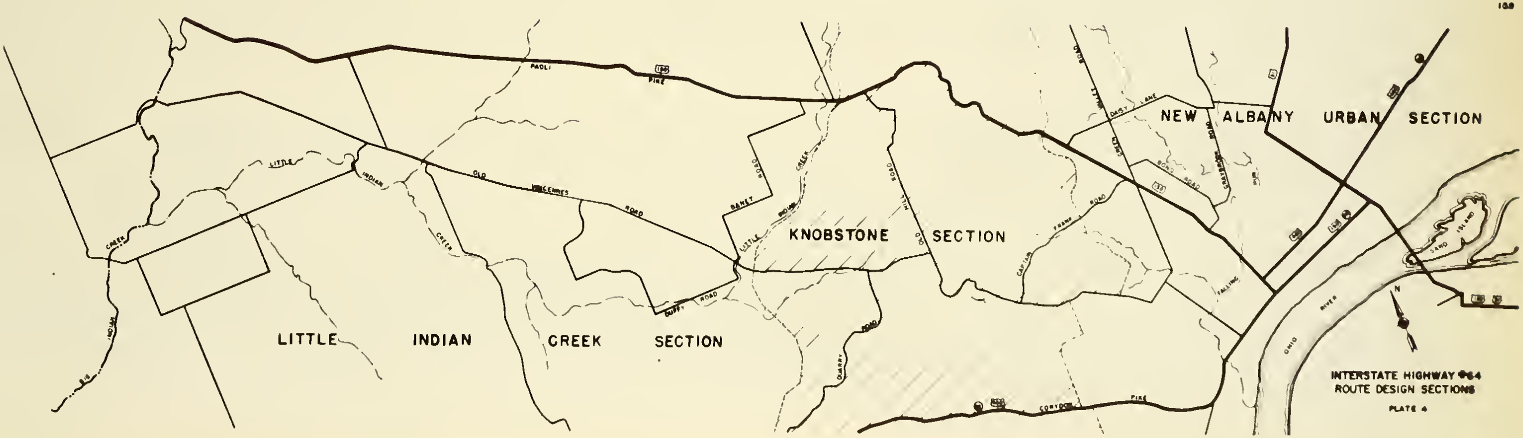
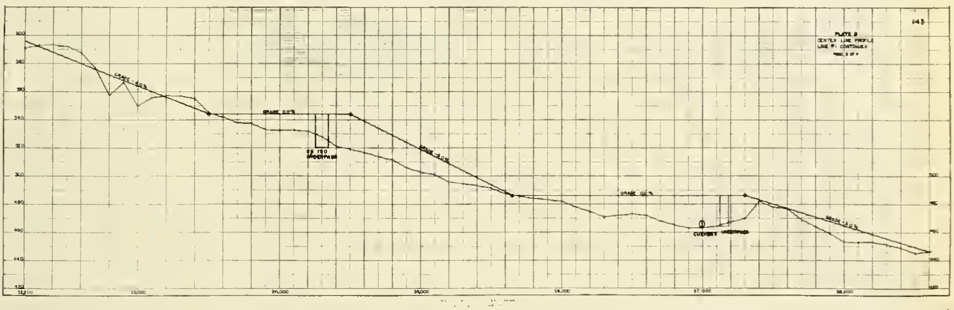


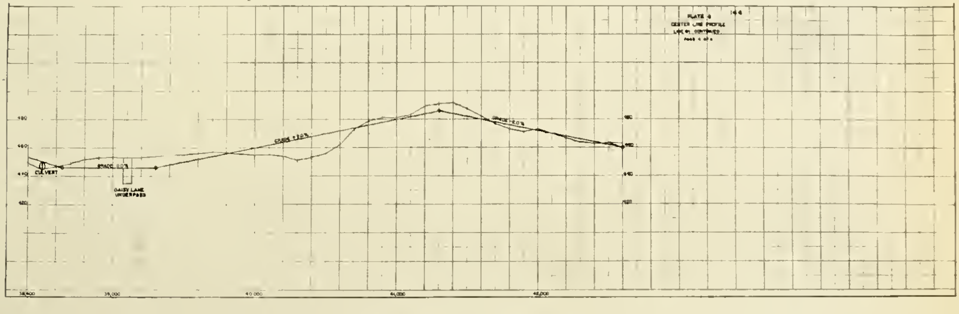
INTERSTATE HIGHWAY #64
ROUTE DESIGN SECTIONS
PLATE 4

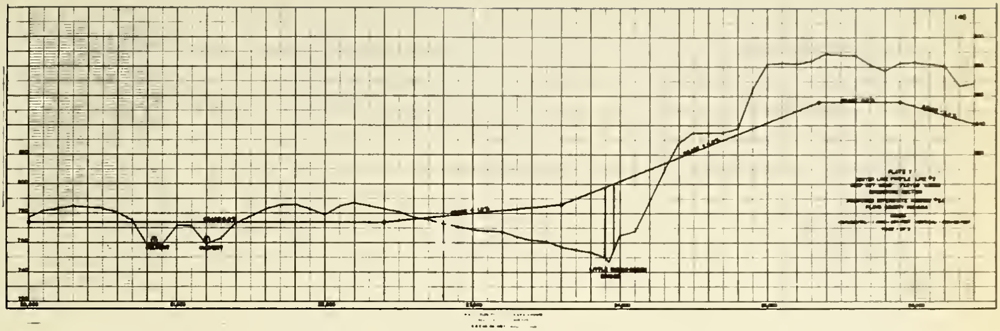
PLATE 5

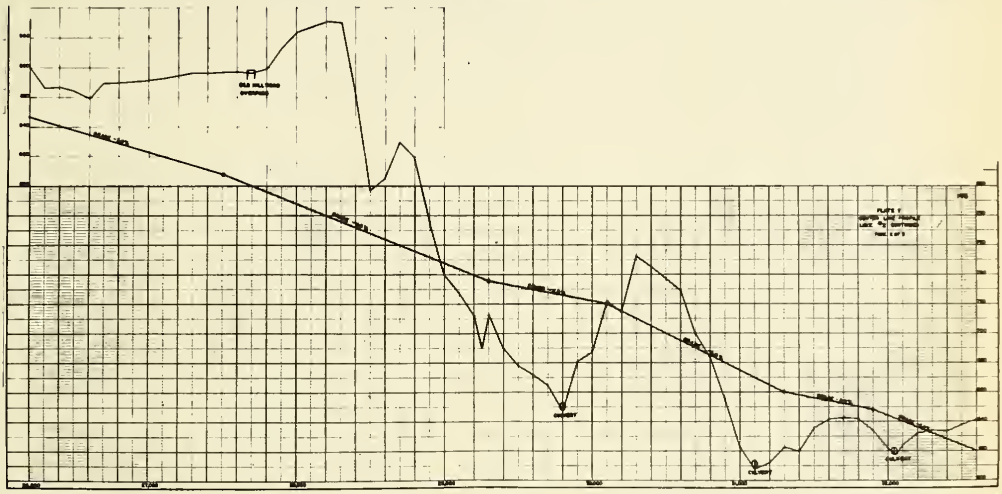

141
CULVERT

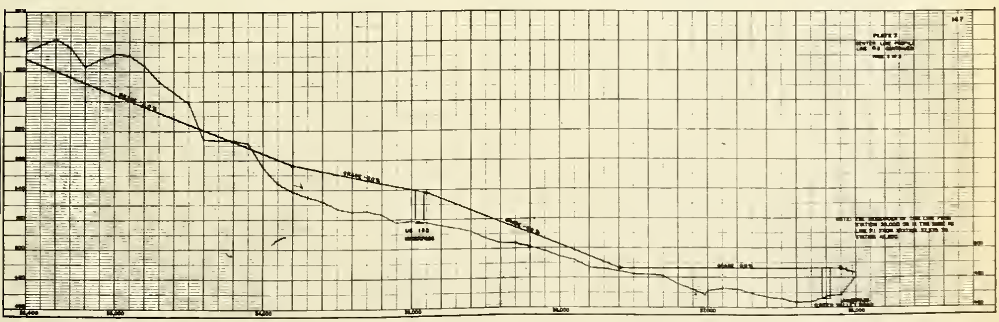

142
PLATE 6
TUNNEL
CULVERT
27,000
28,000
30,000
31,000
32,000


143
PLATE 6
CULVERT


144
PLATE 6
CENTER LINE PROFILE
CULVERT
DAISY LANE
UNDERPASS





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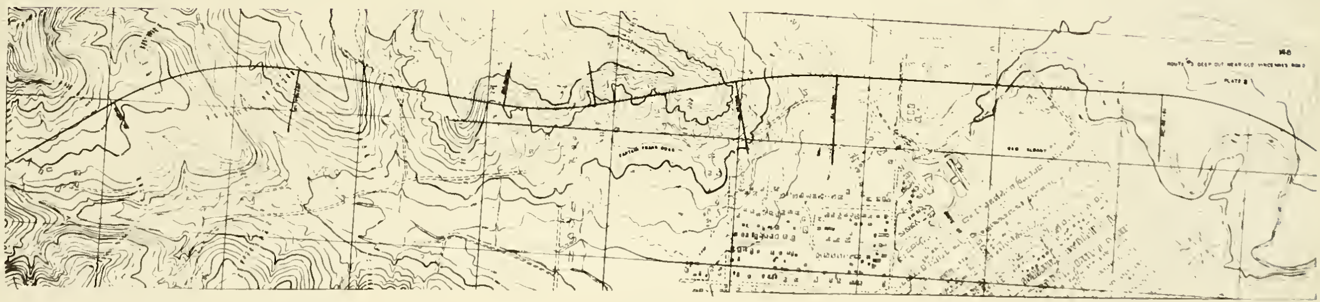
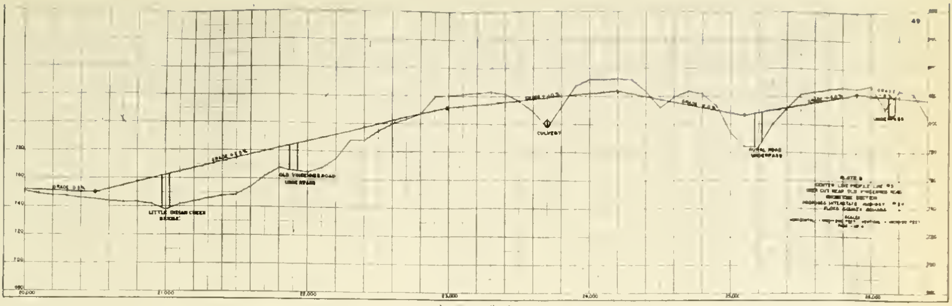
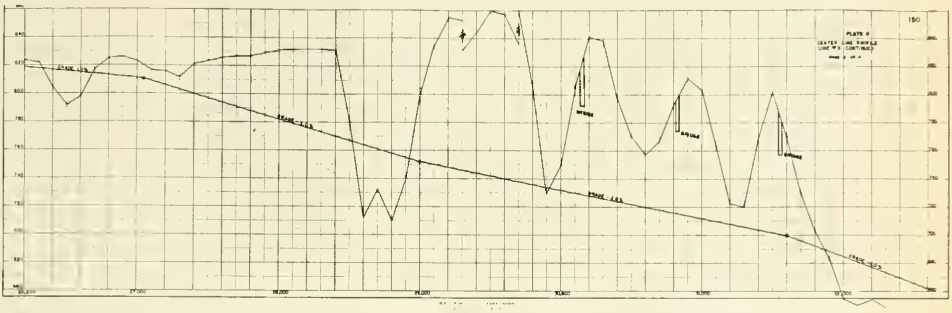
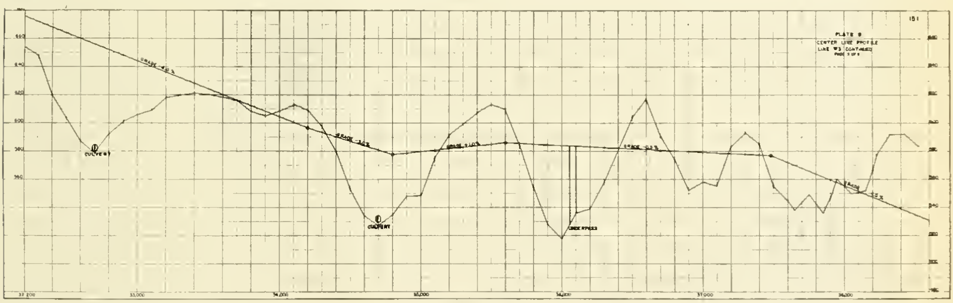
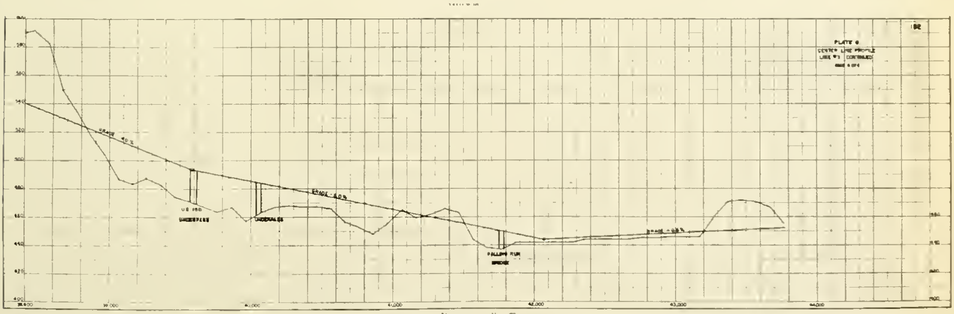



49
CULVERT
OLD VINCENNES ROAD UNDERPASS
PLATE 9
CENTER LINE PROFILE LINE #3


150
PLATE 9
CENTER LINE PROFILE
LINE #3 CONTINUED
BRIDGE


151
PLATE 9
CENTER LINE PROFILE
LINE #3 CONTINUED
CULVERT
UNDERPASS


152
PLATE 9
CENTER LINE PROFILE
LINE #3 CONTINUED
US 150
UNDERPASS
BRIDGE

APPENDIX A

APPENDIX A

MAP ASSEMBLY BY STATE PLANE COORDINATES

Before describing how state plane coordinate were used for the map assembly a brief discussion of state plane coordinates would be in order. In the early days of highway surveying because the system or projects were of purely local interest there was no thought given to relating the highway survey to other than local property lines and controls. Previous to 1933 a few larger cities felt the need for a highly accurate control network over an area basis and cities, such as New York and Pittsburgh, used a local system of rectangular tangent-plane coordinates(43). These, however, could not be extended to large regions without introducing serious errors. Recently because of the emphasis on the interregional nature of highways, the need for relating horizontal positions of one highway survey with another, has prompted the use of coordinates established by the U. S. Coast and Geodetic Survey.

Utilization of U. S. Coast and Geodetic Survey astronomic or geodetic positions of known lattitude and longitude would be unrealistic because the local surveyor is generally unskilled in astronomy or geodesy. To surmount this problem the U. S. Coast and Geodetic Survey in 1933 began the establishment of rectangular state plane coordinates systems. Every state now has its own coordinate system. It should be

made clear though that there is no special surveying called state plane surveying and no points have been established as state plane coordinate stations but rather geodetic positions can be readily converted to state coordinate equivalents and then "latitude and departure" calculations of ordinary plane surveying of at least third order accuracy can be used to connect the plane surveying into the geodetic positions. If the plane survey is of high accuracy and closes precisely from one geodetic position on another, points on the plane survey can with confidence in their accuracy be readily converted into geodetic positions.

Two types of state plane coordinate grids have been developed in the U. S. Both are classified as conformal as they are made such that the scale on any surface is the same in all directions. The Lambert conic conformal grid is adapted to states whose greatest length is in an east west direction. States with a long north south dimension such as Indiana use the Transverse mercator. Transverse mercator can be described as a projection of a sphere onto a cylinder, the axis of the cylinder being tilted 90 degrees from the earth's axis so that the cylinder's axis lies in the plane of the equator. The projection onto the cylinder is then considered to be flattened out into a plane surface. In order to have the average projection scale of the sphere equal to the scale of the cylinder the diameter of the cylinder is made slightly smaller than the sphere's diameter. There are then on the transvers mercator projection only two places where the scale

shown is exact. These two places are at the intersection of the cylinder and the sphere. The scale shown between these two lines traced by the intersection of the two surfaces is slightly smaller than true scale, and outside of these lines traced by the intersection of the surfaces the scale shown is slightly greater than true scale. In order to keep these differences between projected and true scale less than one part in 30,000 the difference between the two diameters is kept very small and this in turn necessitates dividing the state of Indiana into two zones. Indiana has an east zone and west zone which overlap and either zone can be used for the overlapping area (see Figure 33).

Calculation of State Plane Coordinates for Transit Station Number 2004. U. S. Geological Survey, New Albany Quadrangle -

Description:

1. 2700 feet east of the intersection of Daisy Lane and Green Valley Road at the intersection of Daisy Lane and a road branching north.
2. Latitude = 38° 18' 36."61. (ϕ)
3. Longitude = 85° 49' 37."61. (λ)

Zone:

By inspection of the map in the coordinate tables (32). The station is found to be in the east zone of Indiana. The central meridian of the east zone is defined as 85° 40' 00."00 west longitude which is assigned the coordinate value of 500,000.

FIG. 33

TRANSVERSE MERCATOR PROJECTION
STATE PLANE COORDINATE ZONES FOR INDIANA

Calculations:

Difference in longitude from central Meridian

		85° 40' 00".00
		-85° 49' 37".61
		- 0° 9' 37".61
in seconds		-577".61
$(\frac{\Delta\lambda}{100})^2 = (-5.7761)^2$	=	33.3633

H from tables

H for 38° 18' 00".0	=	79.719310
Interpolation for 36".61		
-304.08 x 36".61	=	- .011132
H	=	79.708178

V from tables

V for 38° 18' 00".00	=	1.197902
Interpolation for 36.61		
2.77 x 36".61	=	+ 101
V	=	1.198003

a from tables

a for 38° 18' 36".61	=	.885

b from tables

Interpolation for 577.61

a for 500	=	0.937
a for 600	=	1.119
diff	=	0.182

Correction for 77.61 = .182 x 77.61 = .142

b = 0.937 + .141 = 1.078

a x b = -.885 x 1.078 = -.954

$x' = H\,(\Delta\lambda) \mp ab$

= 79.7082 x -577.61 = -46,040.2407

\- .954

x' = 46,039.2867

C from tables

$V.\ (\Delta\lambda/100)^2 \pm c$

$= (1.198003)(33.363) = 39.9693$

$ - .007$

$ 39.9623$

X coordinate $= x' - 500{,}000$

$= 500{,}00$

$-46{,}039.29$

$x = 453{,}960.7$

y from tables

for $38^\circ\ 18'\ 00''.0 = 291{,}307.75$

correction for $36''.6$

$= 36.61 \times 101.15567 = -3703.31$

$y = 295{,}011.06$

Y coordinate $= y + V(\Delta\lambda/100)^2 \pm c$

$= 295{,}011.06$

$+ \quad 39.96$

$295{,}051.02$

Figure 34 shows the form used to calculate state plane Coordinates.

DEPARTMENT OF COMMERCE
U. S. COAST AND GEODETIC SURVEY
Form No. 744b

PLANE COORDINATES ON TRANSVERSE MERCATOR PROJECTION

(Condensed form for calculating-machine computation)

State____________ Zone________ Central meridian____________

Station					
ϕ					
λ					
$\Delta\phi$ (Excess of ϕ over even 10′ expressed as minutes and decimal)					
$\Delta\lambda$ = Central mer. $-\ \lambda$					
$\Delta\lambda''$					
$\left(\frac{\Delta\lambda''}{100}\right)^2$					
H					
V					
a b					
$x' = H.\Delta\lambda \pm ab$					
$V\left(\frac{\Delta\lambda''}{100}\right)^2 \pm c$					
Tabular y					
x					
y					
$\Delta\alpha''$					
$\Delta\alpha$					
Geod. Az. to Az. Mk.					
Grid Az. to Az. Mk.					

M-2450-2

$x = x' + 500{,}000$

$y = \text{Tab. } y + V\left(\frac{\Delta\lambda''}{100}\right)^2 \pm c$

$\Delta\alpha'' = \Delta\lambda'' \sin\phi + d$

Grid Az. = Geod. Az. $-\ \Delta\alpha$

H and V = Tab. H and Tab. V + 2nd. diff. corr'n.

When ab is $\frac{-}{+}$, $\frac{\text{decrease}}{\text{increase}}$ $H.\Delta\lambda$ numerically

d increases $\Delta\lambda''.\ \sin\phi$ numerically

33767

FIG. 34

00 —

Station and Description	Stn.	5	Stn.2242
	T.2S near Sec. of c Dais Gree	line of f way, 2 ft. with ar	Center of concrete walk, on S.W. Side of Summer lodge of Guss Green.
Latitude ϕ	38°	38".47	38° 18' 27".47
Longitude λ	85°	39".72	85° 51' 53".18
$\Delta\phi$(excess of ϕ over 10')			
$\Delta\lambda$=Central Meridian − λ	− 0°	' 39".72	− 0° 11' 53".18
$\Delta\lambda''$	−	.72	− 713.18
$(\Delta\lambda''/100)^2$		901	50.8625
H	7	7612	79.7109569
V		8008	1.1979807
a		885	− .886
b		97	1.321
a.b		148	−1.170
x' = H$\Delta\lambda$ ± a.b	−4	2.895	−56,848.260
c		010	−0.010
V$(\Delta\lambda''100)^2$ ± C		646	60.921
Tabular y	2	99.209	294,086.496
X	4	27.11	443,151.74
Y	2	57.86	294,147.42

Cc
Cc
H

Table 19

— PLANE COORDINATES FOR INDIANA, FLOYD COUNTY, EAST ZONE, CENTRAL MERIDIAN - 85° 40' 00".00 —

Station and Description	Stn. 2003	Traverse Station 2004	Stn. 944 = 2000 = 2119	Stn. 2221	Stn 2227	Stn 2235	Stn. 2242
	T.2S., R.6E., near center of Sec. 27, center of crossroads, Daisy Lane and Green Valley rds.	2700 ft. E. of Daisy Lane and Green Valley Road at the intersection of Daisy Lane and a road north.	Center of cross-roads at Gulf and D-X service stations.	Y-road SW.	Y-road	Center line of right of way, opposite 2 ft. red oak with triangular blaze.	Center of concrete walk, on SW. Side of Summer lodge of Guss Gree .
Latitude ϕ	38° 18' 36".12	38° 18' 36".61	38° 18' 00".56	38° 18' 42.06"	38° 18' 47.56	38° 18' 38".47	38° 18' 27".47
Longitude λ	85° 50' 11".49	85° 49' 37".61	85° 50' 11".36	85° 50' 49".47	85° 51' 17".62	85° 51' 39".72	85° 51' 53".18
$\Delta\phi$ (excess of ϕ over 10')							
$\Delta\lambda$ = Central Meridian - λ	- 0° 10' 11".49	- 0° 09' 37".61	- 0° 10' 11".36	- 0° 10' 49".47	- 0° 11' 17".62	- 0° 11' 39".72	- 0° 11' 53".18
$\Delta\lambda''$	- 611.49	- 577".61	- 611.36	- 649.47	- 677.62	- 699.72	- 713.18
$(\Delta\lambda''/100)^2$	37.392	33.3633	37.376	42.181	45.917	48.961	50.8625
H	79.709476	79.708178	79.717315	79.706233	79.704848	79.707612	79.7109569
V	1.198002	1.198003	1.197920	1.198020	1.198033	1.198008	1.1979807
a	- .885	-0.885	-.887	- .885	- .885	- .885	- .886
b	1.139	1.078	1.139	1.207	1.258	1.297	1.321
a.b	-1.008	-0.954	-1.010	-1.068	-1.113	-1.148	-1.170
$x' = H\Delta\lambda \pm a.b$	-48,740.539	-46.039.2867	-48,734.908	-51,765.668	-54,008.484	-55,772.895	-56,848.260
c	-0.007	-0.007	-0.007	-0.009	-0.009	-0.010	-0.010
$V(\Delta\lambda''100)^2 \pm c$	44.788	39.9623	44.757	50.525	55.001	58.646	60.921
Tabular y	294,961.49	295,011.06	291,971.331	295.623.051	296,118.714	295,199.209	294,086.496
X	451,259.46	453.960.7	451,[illegible].03	448,234.33	445.991.51	444,227.11	443,151.74
Y	295,006.27	295,051.02	292,016.08	295,673.57	296,173.71	295,257.86	294,147.42

Coordinate X = x' + 500,000
Coordinate Y = Tabular $y = V(\Delta\lambda''/100)^2$ c
H and V = Tabular H and Tabular V

When a.b is - decrease H. numerically
When a.b is + increase H. Numerically

)INATES Cont'd 2.

Station and Description	S	Traverse Stn. 117	T. Stn 101
	Y o a	U. S. C.+ G. S. Triangulation Station Bangs 1879-1933	U. S. C.+ G. S. azimuth mark. to Bangs triangulation Station azimuth mark pre 1947
Latitude ϕ	3	38° 19' 36".617	38° 19' 01".82
Longitude λ	8	85° 51' 17".255	85° 51' 12".75
$\Delta\phi$ (excess of ϕ over 10')	-		
$\Delta\lambda$ = Central Meridian - λ	-		- 0° 11' 12".75
$\Delta\lambda''$			- 67 .75
$(\Delta\lambda''/100)^2$			45.259
H	1		79.700511
V			1.198073
a			- .884
b			1.249
a.b			-1.104
x' = H $\Delta\lambda$ ± a.b			-53,617.41
c			-0.009
V($\Delta\lambda$ "100)^2 ± C			54.214
Tabular y			297,561.19
X		446,033.10	446,382.
Y		301,136.06	297,615.4

Table 19

PLANE COORDINATES Cont'd 2.

Station and Description	Stn 2245.	T. St 2249	Stn 2252	T. Stn 2255	Stn. 2258	Traverse Stn. 117	T. Stn 101
	Y-intersection on old Vincennes and old Hill rds.	Intersection of old Vincennes and Quarry rds.	Private road N. along small branch, on E. side of bridge	Y-rd. W., opposite green mail box	Standard tablet "TT45 D 37" in concrete, 5 ft. N., 35 ft. W. of intersection of Old Vincennes, Duffy, and Banet rds.	U. S. C.+ G. S. Triangulation Station Bangs 1879-1933	U. S. C.+ G. S. azimuth mark. to Bangs triangulation Station azimuth mark pre 1947
Latitude ϕ	38° 18' 12".34	38° 18' 15".95	38° 18' 22".43	38° 18' 32".51	38° 18' 40".56	38° 19' 36".617	38° 19' 01".82
Longitude λ	85° 52' 08".32	85° 52' 42".76	85° 53' 01".51	85° 53' 36".62	85° 53' 48".55	85° 51' 17".255	85° 51' 12".75
$\Delta\phi$ (excess of ϕ over 10')							
$\Delta\lambda$ = Central Meridian − λ	− 0° 12' 08".32	− 0° 12' 42".76	− 0° 13' 01".51	− 0° 13' 36".62	− 0° 13' 48".55		− 0° 11' 12".75
$\Delta\lambda''$	− 728.32	− 702.76	− 781.51	− 816.62	− 828.55		− 67 .75
$(\Delta\lambda''/100)^2$	53.045	58.180	61.070	66.687	68.649		45.259
H	79.7155577	79.714599	79.712 [illegible]	79.709425	79.706977		79.700511
V	1.197936.18	1.197946	1.197964	1.197992	1.198014		1.198073
a	− .884	− .885	− .885	− .885	− .885		− .884
b	1.347	1.408	1.438	1.502	1.522		1.249
a.b	-1.191	-1.246	-1.273	-1.329	-1.347		-1.104
$x' = H\Delta\lambda \pm a.b$	-58,057.2	-60,180.754	-62,294.835	-65,090.981	-66,039.869		-53,617.41
c	-0.012	-0.013	-0.013	-0.015	-0.017		-0.009
$V(\Delta\lambda''100)^2 \pm c$	63.531	69.683	73.154	79.875	82.226		54.214
Tabular y	292,556.11	292,921.183	293,576.672	294,596.321	295,410.624		297,561.19
X	441,943	439,198.	437,705.15	434,909.02	433,960.13	446,033.10	446,382.
Y	292,619.64	292,990.86	293,649.83	294,676.2	295,492.85	301,136.06	297,615.4

APPENDIX 3

TABLE 20 EARTHWORK QUANTITIES

ROUTE #1 - TUNNEL ROUTE

Station to Station	Elevation (in feet) Ground	Grade	Depth (in feet) Cut	Fill	Section Length (in feet)	Area of Station (sq. yds.)	Average Area (sq. yds.)	Volume (in cu. yds.) Cut	Fill
200 00	827	824	3		0	53.3	0	0	0
201 00	827	822	5		100	93.3	73	2433	
202 00	821	820	1		100	16.9	55	1833	
202 11	819.8	819.8	0		11	0	8	29	
203 00	807	818		11	89	185.8	93		2759
204 00	800	816		16	100	288.0	237		7899
205 00	781	814		33	100	718.7	503		16765
205 50	777	813		36	50	808.0	763		12719
206 00	793	812		19	50	354.7	581		9685
207 00	805	814		9	100	148.0	301		10032
208 00	815	816		1	100	14.8	81		2700
208 20	816.4	816.4		0	20	0	7		47
209 00	823	818	5		80	93.3	47	1253	
210 00	825	820	5		100	93.3	93	3100	
211 00	827	822	5		100	93.3	93	3100	
212 00	828	824	4		100	72.9	83	2766	
213 00	827	826	1		100	16.9	45	1500	
214 00	825	823	2		100	34.7	26	867	
215 00	825	820	5		100	93.3	64	2133	
216 00	823	817	6		100	109.8	101	3366	
217 00	815	814	1		100	16.9	63	2100	
217 40	812.8	812.8	0		40	0	8	107	
218 00	809	811		2	60	30.7	15		300
218 20	810.4	810.4		0	20	0	15		100
219 00	815	808	7		80	131.4	66	176	
220 00	809	805	4		100	72.9	102	3400	
221 00	805	802	3		100	53.3	63	2100	
222 00	802	799	3		100	53.3	53	1766	
222 75	797	797	0		75	0	27	675	
223 00	795	796		1	25	14.8	7		58

TABLE 20 (continued)

Station to Station	Elevation (in feet) Ground	Grade	Depth (in feet) Cut	Fill	Section Length (in feet)	Area of Station (sq. yds.)	Average Area (sq. yds.)	Volume (in cu. yds.) Cut	Fill
224 00	788	793		5	100	83.3	49		1633
225 00	787	790		3	100	47.3	65		2166
226 00	787	787		0	100	0	29		967
227 00	787	784	3		100	53.3	27	900	
228 00	785	781	4		100	72.9	63	2100	
229 00	782	778	4		100	72.9	73	2433	
230 00	777	777	0		100	0	37	1233	
231 00	777	776	1		100	16.9	8	267	
232 00	778	775	3		100	53.3	35	1167	
233 00	778	774	4		100	72.9	63	2100	
234 00	776	773	3		100	53.3	63	2100	
235 00	774	772	2		100	34.7	44	1467	
236 00	771	771	0		100	0	17	567	
237 00	768	770		2	100	30.7	15		500
238 00	768	769		1	100	14.8	23		767
239 00	768	768		0	100	0	7		233
240 00	769	769		0	100	0	0	0	0
241 00	766	770		2	100	30.7	15		500
242 00	767	771		4	100	64.9	49		1633
243 00	765	772		7	100	112.0	88		2933
244 00	762	773		11	100	185.8	149		4966
245 00	760	774		14	100	245.8	216		7199
246 00	768	775		7	100	112.0	179		5977
247 00	774	776		2	100	30.7	71		2366
247 65	776.6	776.6	0		65	0	15		325
248 00	778	777	1		35	16.9	8	93	
249 00	787	778	9		100	175.0	96	3200	
250 00	782	779	3		100	53.3	114	3800	
251 00	796	780	16		100	320.0	187	6232	
252 00	813	781	32		100	753.8	537	17898	

TABLE 20 (continued)

Station to Station	Elevation (in feet) Ground	Grade	Depth (in feet) Cut	Fill	Section Length (in feet)	Area of Station (sq. yds.)	Average Area (sq. yds.)	Volume (in cu. yds.) Cut	Fill
253 00	821	782	39		100	979.3	866	28864	
254 00	820	783	37		100	541.6	760	25330	
255 00	819	784	35		100	506.5	524	17464	
256 00	814	782	32		100	455.1	481	16031	
257 00	818	780	38		100	559.4	507	16898	
258 00	822	778	44		100	670.0	615	20498	
259 00	831	776	55		100	887.6	779	25964	
260 00	832	774	58		100	950.6	919	30630	
261 00	856	771							
262 00	892	768							
263 00	913	765							
264 00	923	762							
265 00	923	759							
266 00	923	756							
267 00	923	753							
268 00	922	750							
269 00	917	747							
270 00	911	744							
271 00	914	741							
272 00	895	738							
273 00	888	735							
274 00	885	732							
275 00	883	729							
276 00	905	726							
277 00	912	723							
278 00	890	720							
279 00	833	717							
280 00	785	714							
281 00	738	711	27		0	372.8			
282 00	708	708	0	0	100	0	186	6199	

TABLE 20 (continued)

Station to Station	Elevation (in feet) Ground	Grade	Depth (in feet) Cut	Fill	Section Length (in feet)	Area of Station (sq. yds.)	Average Area (sq. yds.)	Volume (in cu. yds.) Cut	Fill
283 00	697	706.5		9.5	100	111	56		1866
284 00	691	705.0		14	100	177.3	144		4800
285 00	699	703.5		4.5	100	52.0	115		3832
285 25	703.1	703.1		0	25	0	26		217
286 00	715	702.0	13		75	164.3	82	2050	
287 00	718	700.5	17.5		100	227.5	196	6533	
288 00	730	699.0	31		100	438.3	333	11099	
289 00	717	697.5	19.5		100	257.0	348	11600	
290 00	707	696.0	11.0		100	137.2	197	6566	
290 30	695.5	695.5	0		30	0	69	690	
291 00	670	694.5		24.5	70	367.5	184		4293
292 00	628	692.0		64.0	100	1522	948		31597
293 00	625	688.0		63.0	100	1484.0	1503		50094
294 00	624	684.0		60.0	100	1373.3	1429		47629
295 00	640	680.0		40	100	737.8	1056		35196
296 00	655	676.0		21	100	298.7	518		17265
296 75	673	673		0	75	0	149		3725
297 00	678	672	6		25	72.3	36	300	
298 00	684	668	16		100	206.2	139	4633	
299 00	687	664	23		100	309.9	258	8599	
300 00	698	660	38		100	559.4	435	14499	
301 00	691	656	35		100	506.5	533	17765	
302 00	668	652	17		100	220.5	363	12099	
303 00	658	648	10		100	123.9	172	5733	
304 00	656	644	12		100	150.7	137	4566	
304 94	640.2	640.2	0	0	94	0	75	2350	
305 00	639	640		1	6	12.2	6		12
306 00	621	636		15	100	227	120		4000
307 00	613	632		19	100	304	265		8832
308 00	606	628		22	100	366.7	335		11165

TABLE 20 (continued)

Station to Station	Elevation (in feet) Ground	Grade	Depth (in feet) Cut	Fill	Section Length (in feet)	Area of Station (sq. yds.)	Average Area (sq. yds.)	Volume (in cu. yds.) Cut	Fill
309 00	599	624		25	100	433.3	400		13332
310 00	597	620		23	100	388.4	411		13699
311 00	602	616		14	100	208.4	298		9932
312 00	612	612		0	100	0	104		3466
313 00	616	610.4	5.6		100	82	41	1367	
314 00	616	608.8	7.2		100	116	99	3300	
315 00	613	607.2	5.8		100	97	106	3533	
315 40	696.6	606.6	0		40	0	48	640	
316 00	596.0	605.6		9.6	60	132	61		1220
317 00	577	604.0		27	100	480	306		10199
318 00	600	602.4		2.4	100	30.9	255		8499
318 10	602.2	602.2		0	10	0	15		50
319 00	611.0	600.8	10.2		90	176	9	270	
320 00	610.0	599.2	10.8		100	196	19	633	
320 58	598.3	598.3	0		58	0	10	193	
321 00	590.0	597.6		7.6	42	102	51		1428
321 50	568.0	596.8		28.8	50	548.0	325		5418
322 00	591.0	596.0		5.0	50	70.0	309		5151
322 80	592.8	592.8	0	0	80	0	35		934
323 00	593.0	590.0	3		20	46.7	23	153	
324 00	593.0	588.0	5		100	82.2	64	2133	
325 00	592.0	584.0	8.0		100	135.1	109	3633	
326 00	588.0	580.0	8.0		100	135.1	135	4500	
327 00	577	576.0	1.0		100	14.7	75	2500	
327 06	575.8	575.8	0	0	06	0	7	14	
328 00	558	572		14	94	208.4	104		3258
329 00	567	568		1	100	12.2	110		3666
330 00	550	564		14	100	208.4	110		3666
331 00	556	560		4	100	54.2	131		4366
331 80	556.8	556.8	0	0	80	0	27		720

TABLE 20 (continued)

Station to Station	Elevation (in feet) Ground	Grade	Depth (in feet) Cut	Fill	Section Length (in feet)	Area of Station (sq. yds.)	Average Area (sq. yds.)	Volume (in cu. yds.) Cut	Fill
332 00	557	556.0	1		20	14.7	7	47	
333 00	557	552	5		100	32.2	48	1600	
334 00	555	548	7		100	116	99	3300	
335 00	545	544	1		100	14.7	65	2166	
335 38	544	544	0	0	38	0	7	89	
336 00	542	544		2	62	25.3	13		269
337 00	538	544		6	100	78.7	52		1733
338 00	537	544		7	100	93.3	86		2866
339 00	533	544		11	100	156.4	125		4166
340 00	533	544		11	100	156.4	156		5199
341 00	533	544		11	100	156.4	156		5199
342 00	532	544		12	100	173.3	167		5566
343 00	528	544		16	100	245.3	209		6966
343 50	524	544		20	50	314.0	280		4668
344 00	521	544		23		Bridge			
344 50	520	544		24		410.7			
345 00	519	544		25	50	433.3	422		7035
346 00	517	539		22	100	366.7	400		13332
347 00	514	534		20	100	324.4	345		11499
348 00	512	529		17	100	264.4	294		9799
349 00	506	524		18	100	284.0	274		9132
350 00	503	519		16	100	245.3	264		8799
351 00	501	514		13	100	190.7	218		7266
352 00	496	509		13	100	190.7	191		6366
353 00	495	504		9	100	124.0	157		5233
354 00	493	499		6	100	78.7	101		3366
355 00	491	494.0		3	100	39.3	59		1966
356 00	487	489.0		2	100	25.3	32		1066
356 50	486	486		0	50	0	13		217
357 00	485	486		1	50	12.2	6		100
358 00	484	486		2	100	25.3	19		633
359 00	483	486		3	100	39.3	32		1067

TABLE 20 (continued)

Station to Station	Elevation (in feet) Ground	Grade	Depth (in feet) Cut	Fill	Section Length (in feet)	Area of Station (sq. yds.)	Average Area (sq. yds.)	Volume (in cu. yds.) Cut	Fill
360 00	482	486		4	100	54.2	47		1567
361 00	478	486		8	100	108.4	81		2700
361 50	475	486		9.5	50	132.0	120		2000
362 50	475	486		11	0	Bridge	0		
363 00	471	486		15	50	226.7	209		3484
364 00	472	486		14	100	208.4	218		7266
365 00	473	486		13	100	190.7	200		6666
366 00	472	486		14	100	208.4	200		6666
367 00	486	486		18	100	284.0	246		8199
368 00	465	486		21	100	345.3	315		10499
369 00	463	486		23	100	388.4	367		12232
370 00	463	486		23	100	388.4	388		12932
371 00	464	486		21	100	345.3	367		12232
372 00	467	486		19	100	304.0	330		10999
373 00	470	486		16	100	245.3	275		9165
374 00	482	483		1	100	12.2	129		4300
375 00	478	480		2	100	25.3	19		633
376 00	477	477	0	0	100	0	13		433
377 00	469	474		5	100	70.0	35		1166
378 00	464	471		7	100	93.3	82		2733
379 00	459	468		9	100	124.0	109		3633
380 00	453	465		12	100	173.3	149		4966
381 00	453	462		9	100	124.0	149		4966
382 00	453	459		6	100	78.7	101		3366
383 00	452	456		4	100	54.2	66		2200
384 00	449	453		4	100	54.2	54		1800
385 00	445	450		5	100	70	62		2066
386 00	447	447		0	100	0	35		1167
386 40	448	446	2		40	30.2	15	200	
387 00	449	446	3		60	46.7	38	760	

TABLE 20 (continued)

Station to Station	Elevation (in feet)		Depth (in feet)		Section Length (in feet)	Area of Station (sq. yds.)	Average Area (sq. yds.)	Volume (in cu. yds.)	
	Ground	Grade	Cut	Fill				Cut	Fill
388 00	452	446	6		100	97.3	72	2400	
389 00	453	446	7		100	115.9	107	3566	
390 00	453	446	7		100	115.9	116	3866	
391 00	453	446	7		100	115.9	116	3866	
392 00	453	446	7		100	115.9	116	3866	
393 00	454	446	8		100	135.1	125	4166	
394 00	455	448	7		100	115.9	125	4166	
395 00	455	450	5		100	82.2	99	3300	
396 00	456	452	4		100	64.0	73	2433	
397 00	457	454	3		100	46.7	55	1833	
398 00	457	456	1		100	14.7	31	1033	
398 30	456.6	456.6	0		30	0	7	70	
399 00	456.0	458		2	70	25.3	13		303
400 00	455	460		5	100	70.0	43		1433
401 00	455	462		7	100	93.3	82		2733
402 00	454	464		10	100	140	117		3900
403 00	451	466		15	100	226.7	183		6099
404 00	453	468		15	100	226.7	227		7566
405 00	458	470		12	100	173.3	200		6666
406 00	462	472		10	100	140.0	157		5233
407 00	473	474		11	100	156.4	148		4933
407 25	474.5	474.5		0	25	0	78		650
408 00	479	476	3		75	46.7	23	575	
409 00	481	478	3		100	46.7	47	1566	
410 00	481	480	1		100	14.7	31	1033	
411 00	483	482	1		100	14.7	15	500	
412 00	489	484	5		100	82.2	48	1600	
413 00	491	486	5		100	82.2	82	2733	
414 00	492	484	8		100	135.1	109	3633	
415 00	487	482	5		100	82.2	109	3633	

TABLE 20 (continued)

Station to Station	Elevation (in feet) Ground	Grade	Depth (in feet) Cut	Fill	Section Length (in feet)	Area of Station (sq. yds.)	Average Area (sq. yds.)	Volume (in cu. yds.) Cut	Fill
416 00	482	480	2		100	30.2	56	1866	
416 60	478.8	478.8	0		60	0	15	300	
417 00	477	478		1	40	12.2	6		80
418 00	473	476		3	100	39.3	41		1367
419 00	471	474		3	100	39.3	39		1300
419 75	472.5	472.5	0	0	75	0	20		500
420 00	473	472.0	1		25	14.7	7	58	
420 80	470.4	470.4	0	0	80	0	7	187	
421 00	470	470	0	0	20	0	0	0	0
422 00	467	468		1	100	12.2	6		200
423 00	464	466		2	100	25.3	19		633
424 00	463	464		1	100	12.2	19		633
424 50	463	463		0	50	0	6		100
425 00	463	462	1		50	14.7	7	117	
426 00	463	460	3		100	46.7	31	1033	
								459,651	716,618

TABLE 21 EARTHWORK QUANTITIES

ROUTE #2 DEEP CUT NEAR FLOYDS KNOBS

Station to Station	Elevation (in feet) Ground	Grade	Depth (in feet) Cut	Fill	Section Length (in feet)	Area of Station (sq. yds.)	Average Area (sq. yds.)	Volume (in cu. yds.) Cut	Fill
200 00	777	774	3			53.3			
201 00	782	774	8		100	152.9	103	3433	
202 00	783	774	9		100	175.0	164	5466	
203 00	785	774	11		100	221.5	198	6599	
204 00	784	774	10		100	197.8	210	6999	
205 00	783	774	9		100	175.0	186	6199	
206 00	781	774	7		100	131.4	153	5099	
207 00	775	774	1		100	16.9	74	2466	
207 08	774	774	0		8		8	21	
208 00	759	774		15	92	266.7	133		4079
209 00	759	774		15	100	266.7	267		8899
210 00	772	774		2	100	30.7	149		4966
211 00	771	774		3	100	47.3	39		1300
212 00	759	774		15	100	83.3	65		2166
213 00	763	774		11	100	185.8	135		4500
214 00	773	774		1	100	14.8	100		3333
214 18	774	774		0	18		7		42
215 00	778	774	4		82	72.9	36	984	
216 00	783	774	9		100	175.0	124	4133	
217 00	785	774	11		100	221.5	198	6599	
218 00	786	774	12		100	229.3	225	7499	
219 00	783	774	9		100	175.0	202	6733	
220 00	779	774	5		100	93.3	134	4466	
221 00	785	774	11		100	221.5	157	5233	
222 00	787	774	13		100	251.3	236	7866	
223 00	785	774	11		100	221.5	236	7866	
224 00	783	774	9		100	175	198	6599	
225 00	781	775	6		100	109.8	142	4733	
226 00	777	776	1		100	16.9	63	2100	
226 30	776.3	776.3	0		30		8	80	

TABLE 21 (continued)

Station to Station	Elevation (in feet) Ground	Grade	Depth (in feet) Cut	Fill	Section Length (in feet)	Area of Station (sq. yds.)	Average Area (sq. yds.)	Volume (in cu. yds.) Cut	Fill
227 00	776	777		1	70	14.8	7		163
228 00	773	778		5	100	83.3	49		1633
229 00	771	779		8	100	129.8	107		3566
230 00	769	780		11	100	185.8	158		5266
231 00	768	781		13	100	225.3	206		6866
232 00	767	782		15	100	266.7	246		8199
233 00	764	783		19	100	354.7	311		10366
234 00	762	784		22	100	366.7	361		12032
235 00	761	785		24	100	410.7	389		12965
236 00	757	786		29	100	528.4	470		15665
237 00	755	790		35	100	684.4	606		20198
238 00	753	794		41	100	856.4	770		25664
239 00	750	798		48	100	1077.3	967		32230
240 00	765	802		37	100	740.0	909		30297
241 00	768	806		38	100	768.4	754		25131
242 00	787	810		23	100	388.4	578		19264
243 00	810	814		4	100	54.2	221		7366
243 30	815.2	815.2		0	30		27		270
244 00	828	818	10		70	150.5	75	175	
245 00	835	822	13		100	197.8	174	5799	
246 00	835	826	9		100	134.7	166	5533	
247 00	835	830	5		100	73.2	104	3466	
248 00	838	834	4		100	58.2	66	2200	
249 00	865	838	27		100	444.6	251	8366	
250 00	882	842	40		100	702	573	19098	
251 00	883	846	37		100	640.5	671	22364	
252 00	882	850	32		100	896	768	25597	
253 00	884	854	30		100	501.7	699	23298	
253 50	887	856	31		50	521.0	511	8518	
254 00	889	856	33		50	596.9	559	9318	
255 00	888	856	32		100	391.1	494	16465	

TABLE 21 (continued)

Station to Station	Elevation (in feet) Ground	Grade	Depth (in feet) Cut	Fill	Section Length (in feet)	Area of Station (sq. yds.)	Average Area (sq. yds.)	Volume (in cu. yds.) Cut	Fill
256 00	887	856	31		100	376.3	384	12798	
257 00	881	856	25		100	291.0	334	11132	
258 00	877	856	21		100	237.4	264	8799	
259 00	883	856	27		100	318.7	278	9265	
260 00	883	853	30		100	361.7	340	11332	
261 00	882	850	32		100	391.1	376	12532	
262 00	881	847	34		100	421.2	406	13532	
263 00	867	844	23		100	263.8	346	11399	
264 00	871	841	30		100	361.7	313	10432	
265 00	865	838	27		100	318.7	340	11332	
266 00	860	835	25		100	291.0	305	10165	
267 00	870	832	38		100	483.4	387	12899	
268 00	870	829	41		100	531.9	508	16932	
269 00	871	826	45		100	598.8	565	18831	
270 00	872	823	49		100	668.3	634	21131	
271 00	873	820	53		100	740.5	704	23464	
272 00	875	817	58		100	834.6	788	26264	
273 00	877	814	63		100	932.8	884	29464	
274 00	877	811	66		100	993.7	963	32097	
275 00	878	808	70		100	1077.2	1035	34496	
276 00	878	804	74		100	1163.4	1120	37330	
277 00	877	800	77		100	1229.9	1197	39896	
278 00	880	796	84		100	1381.3	1306	43529	
279 00	894	792	102		100	2023	1702	56728	
280 00	905	788	117		100	2661.7	2342	78059	
281 00	908	784	124		100	3045	2853	95090	
282 00	912	780	132		100	3329.3	3187	106223	
283 00	911	776	135		100	3438.7	3384	112789	
284 00	864	772	92		100	1645.8	2542	84725	
285 00	797	768	29		100	479.4	1063	35430	
286 00	805	764	41		100	724.3	602	20065	

TABLE 21 (continued)

Station to Station	Elevation (in feet) Ground	Grade	Depth (in feet) Cut	Fill	Section Length (in feet)	Area of Station (sq. yds.)	Average Area (sq. yds.)	Volume (in cu. yds.) Cut	Fill
287 00	830	760	70		100	1404	1064	35463	
288 00	820	756	64		100	1251.5	1328	44262	
289 00	775	752	23		100	444.7	848	28264	
289 75	749	749	0		75		222	5550	
290 00	740	748		8	25	108.4	54		450
291 00	728	744		16	100	245.3	177		5899
292 00	712	740		28	100	504.0	375		12499
292 50	690	738		48	50	1077.3	791		13186
293 00	713	736		23	50	388.4	733		12219
294 00	690	734		44	100	948.4	668		22264
295 00	678	732		54	100	1284.0	1116		37196
296 00	672	730		58	100	1430.7	1357		45229
297 00	665	728		63	100	1624	2027		67560
298 00	647	726		79	100	2317.3	1971		65693
299 00	681	724		43	100	917.3	1617		53894
300 00	687	722		35	100	684.4	801		26697
300 95	720.1	720.1		0	95		342		10830
301 00	722	720	2		5	30.2	15	15	
301 85	716	716	0		85		15	255	
302 00	715	715	0		15				
303 00	753	710	43		100	1022.4	511	17032	
304 00	745	705	40		100	924.4	973	32430	
305 00	738	700	38		100	861.3	893	29764	
306 00	729	695	34		100	740.4	801	26697	
307 00	699	690	9		100	155.0	448	14932	
307 90	685.5	685.5	0		90		78	2340	
308 00	684	685		1	10	12.2	6		20
309 00	655	680		25	100	433.3	223		7433
310 00	623	675		52	100	1224.4	829		27630
311 00	608	670		62	100	1585.0	1405		48290
312 00	612	665		53	100	1248.4	1417		47229

TABLE 21 (continued)

Station to Station	Elevation (in feet) Ground	Grade	Depth (in feet) Cut	Fill	Section Length (in feet)	Area of Station (sq. yds.)	Average Area (sq. yds.)	Volume (in cu. yds.) Cut	Fill
313 00	623	660		37	100	740.0	994		33130
314 00	620	658		38	100	768.4	754		25131
315 00	636	656		20	100	324.4	546		18198
316 00	642	654		12	100	173.3	249		8299
317 00	643	652		9	100	124.0	149		4966
318 00	642	650		8	100	108.4	116		3866
319 00	634	648		14	100	208.4	158		5266
320 00	622	644		22	100	366.7	288		9599
320 50	617	642		25	50	433.3	400		6668
321 00	624	640		16	50	245.3	339		5651
322 00	632	636		4	100	54.2	150		5000
322 70	633.2	633.2		0	70		27		630
323 00	634	632	2		30	30.2	15	150	
324 00	633	628	5		100	82.2	56	1866	
325 00	638	624	14		100	242.7	162	5399	
326 00	642	620	22		100	420.4	331	11032	
327 00	636	616	20		100	373.3	397	13232	
328 00	623	612	11		100	196.8	285	9499	
329 00	628	608	20		100	373.3	285	9499	
330 00	632	604	28		100	572.4	323	10766	
331 00	631	600	31		100	654.4	613	20431	
332 00	624	596	28		100	572.4	613	20431	
333 00	613	592	21		100	396.7	485	16165	
334 00	606	588	18		100	328.0	362	12065	
335 00	599	584	15		100	263.3	296	9866	
335 70	581.2	581.2	0		70	0	132	3080	
336 00	573	580		7	30	93.3	47		470
337 00	573	576		3	100	39.3	66		2200
337 75	573	573		0	75	0	20		500
338 00	573	572	1		25	14.7	7	58	
339 00	571	568	3		100	46.7	31	1033	